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THE AMATEUR ELECTRICIAN'S WORKSHOP

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THE AMATEUR ELECTRICIAN'S WORKSHOP

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THE AMATEUR ELECTRICIAN'S WORKSHOP

A Handbook
of Practical
Instruction
in the making
of Electrical
Models and
Appliances

BY

S. R. BOTTONE

Sometime Professor of Electricity and
Magnetism at the Carshalton School
for Cadets; at the Istituto Bellino,
Novara; and at the Collegio
del Carmine, Turin

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AUTHOR'S PREFACE.

SO much interest has been shown by all amateurs in the construction of electrical apparatus, more especially by those who cannot command a well-fitted workshop with unlimited tools, that the author feels that no apology is needed in placing the following pages before them.

All the appliances therein described have been actually made by him, and in the manner indicated; and although the results are not equal in beauty or in finish to those which can be turned out by a worker who has a lathe and other suitable tools at his disposition, yet they *act* well; and this, after all, is the great aim of the maker.

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THE

AMATEUR ELECTRICIAN'S WORKSHOP.

§ 1. In the following series of articles we propose to explain the manner in which the amateur, possessing only those tools usually found in a house, can construct a few of the more important, useful, and interesting pieces of apparatus connected with the science of electricity; and although in consequence of the restrictions placed upon us in the matter of tools, the apparatus will necessarily be somewhat of a primitive character, yet we shall endeavour, not only to point out the principles on which the attainment of the best results depends, but also to carry them out as far as our appliances will permit.

THE ELECTRO-MOTOR.

§ 2. To produce a good continuous current motor, it is necessary that the field magnet should be capable of taking up a high degree of magnetisation; that the armature should run close to the pole pieces in order to secure a powerful torque; and it is very essential, so that there be little or no waste of current by heating, that the armature be laminated. For this reason, we will procure for the construction of the field magnets a piece of that very soft iron known as "hoop iron," such as is used to make the hoops that are put round casks, or the bands for the packing cases. We shall require a piece of that particular brand called "builder's hooping," about 4 ft. long, 1 in. wide, and $\frac{1}{16}$ of an inch thick. This strip we fashion into the shape shown at Fig. 1. To do this neatly we shall require a piece of round broom-handle 1½ ins. in diameter as a pattern for the curvature A, a vice, a pair of pincers, and a flat peen-hammer. We begin by placing one inch of the strip between the jaws of the vice, and then bend the long extremity at right angles to this, as shown at *a a′* in our figure. Great pains must be taken to get a nice square bend, truly at right angles with the first inch; and this can be effected by hammering along the bend. This done, at the point *b*, 2¼ ins. from the first bend, we in precisely similar manner bend the strip at right angles, *outwards*, and then, using the piece of broom-handle as a pattern of the curvature, we bend the iron strip round it for a length of 1⅜ ins. This brings us to the point *c*, whence we continue straight for a length of 2¼ ins., which brings us to *d*. Here we again bend the strip inwardly at right angles, with the same precautions mentioned above, to ensure the angles being quite true and flat. In like manner we make an angle at *d′*, whence we proceed to *e* at 2 ins. from *d′*; and here we bring the piece of broom-handle again into requisition, so as to produce the lower curve of A. Having made as before a curve 1⅜ ins. in length, we proceed straight on to our starting point *a*. From this point, going over the *outside* of the long frame thus produced, we repeat the bends and angles, folding the iron strip over the outside of the frame until two more turns have been laid on, ending at *f*. When this has been successfully accomplished, and the angles, and more especially the circular space, or "tunnel," made quite true—this latter being 1 9/16 ins. in diameter—we fasten the whole firmly together by binding it round (as neatly and as smoothly as cotton is laid on a reel) at the points *a a′* and *d d′*, with one layer of No 22 soft iron wire, finishing off by twisting the ends of each layer together, and cutting off with the pliers. In like manner, binders consisting of three turns of the same gauge (No. 22) of soft iron wire are tightly wound round the points *b*, *c*, *e*, and *e′* just before the beginning of the curvature or tunnel A. This completes the field magnet proper. The spaces between the binders (namely, from *d* to *c* and *b* to *a′* at the top, and *d* to *e* and *c′* to *a′* at the bottom) must be carefully dressed with tape, to prevent any accidental abrasion of the covering of the wire with which the field magnet will eventually be wound, which abrasion would result in electrical leakage. For this purpose we take a piece of tape ¾ in. wide, and beginning at *e′*, close against, and just inside the wire binding, we wrap it tightly around the iron, lapping it over spirally in the direction of *a* until we reach that corner. Here we stitch

Fig. 1.

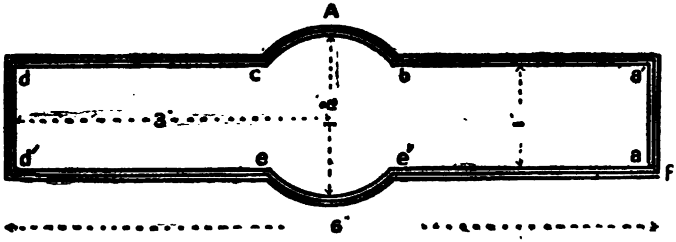


Fig. 2.

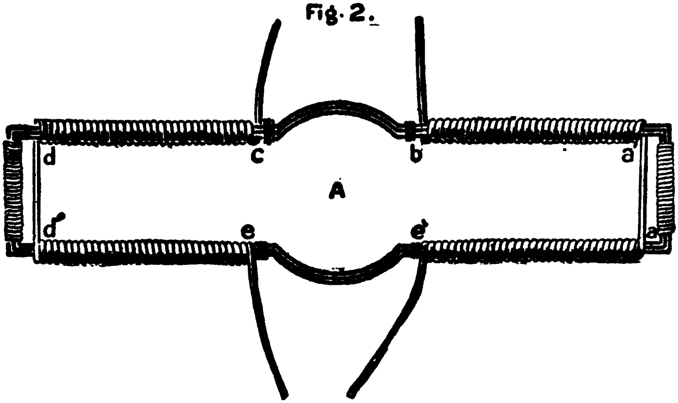


Fig. 3.

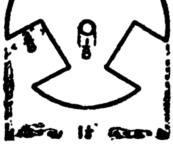


Fig 4

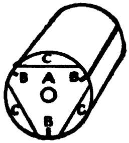
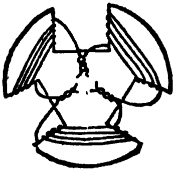


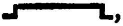
Fig. 5.



it down to the subjacent layer, after which we cut off the superfluity. In order that this "dressing" should lie smoothly, the tape must be pulled very tightly while being wound on. In like manner the spaces *a* to *b*, *c* to *d*, and *d'* to *e* are bound round with tape, after which the taping should be painted over with good shellac varnish. When this is quite dry and hard, we can proceed with the winding.

§ 3. For winding the field magnets we shall need about ¼ lb. (say ten yards) of No. 18 double cotton-covered copper wire, which for convenience of manipulation should be cut into two equal lengths, and made up into two equal and separate hanks, which will pass freely into the openings between *a a'* and *d d'*. Taking one of the hanks, we straighten out about 4 ins. of one end, and tie it firmly with a length of strong silk twist against the binder at *e'*, as shown at Fig. 2, whence we proceed to wind—very tightly, evenly and closely—towards the corner *a*. (The purpose of tying the wire at *e'* is to prevent it from uncoiling after winding.) When the corner *a* has been reached, the winding is continued by passing the hank to the *back* of iron at *a'*, and then winding forwards from *a'* to *b*, where the wire is tied down to the iron by silk twist as before, leaving about 4 ins. projecting, as at the start, for future attachment to the terminals, etc. In order to get proper polarity at the tunnel A, the direction of winding and the mode of crossing over to the upper iron core must be carried out exactly as described and figured; that is, if we begin winding the lower core from *left* over to *right*, and from *right* under to *left*, and so on, we must, on reaching the end of the lower winding, cross over to the upper core, so that in starting the winding near the bend *a'* we wind from *right* over to *left*, and from *left* under to *right*; or, in other words, if viewed from the starting end *e'* and *b*, the direction of winding and of crossing over would look like a letter S. In precisely similar manner, the other two limbs are wound with the other hank of wire, beginning at *e*, going on to *d'*, thence to *d*, and ending at *c*. There will therefore be four projecting pieces of wire—the two commencements at *e'* and *e*, and the two terminations at *b* and *c*. The winding being thus completed, it will be well to give the wire two or three coats of good shellac varnish, allowing each coat to dry thoroughly before applying the succeeding one.

§ 4. Our next task is to make the *armature*. This consists of sufficient soft iron laminations of the form shown at Fig. 3 to make up a depth of about 1 in. These can either be purchased ready made, under the name of "Tripolar" laminations, 1½ ins. in diameter, or the amateur can make them himself, if gifted with a little perseverance, out of any thin pieces of tinned iron, such as old Swiss-milk tins, etc. For this purpose he will begin by choosing a nice flat piece of tinned iron, and striking out on its surface a circle exactly 1½ ins. in diameter with a pair of compasses, taking care to make a distinct mark at the centre. With a pair of snips, or large scissors, he will cut out carefully the circle thus outlined. In like manner he will cut out a sufficient number of discs to make up, when laid one upon the other and tightly pressed down, a column 1 in. in height. Taking one of the discs, he will mark it at three equidistant points round the circumference, and from these points will cut out three squares ⅜ in. deep and ½ in. wide, precisely as shown in the figure. Finally, at the centre mark he will punch or drill a circular hole ⅛ in. in diameter. If he has been careful to make the central hole truly central, and the indentations of the same size and at equal distances apart, he can, after having flattened out this first lamination, use it as a template wherewith to mark the others, which he can then cut out as the first. Having procured the laminations, the next operation is to mount them on a suitable spindle. For this, a piece of round mild steel rod ⅛ in. diameter, 4 ins. long, is required. This should be perfectly straight, and should be cleaned up with a piece of emery cloth. At one inch from the end, a piece of No. 18 bare copper wire (previously cleaned with emery cloth) should be coiled tightly round it, three turns being sufficient. The two ends of the wire being cut off with a pair of pliers, the three turns of the wire are neatly soldered to the spindle, with the aid of a drop of soldering fluid. Having washed the junction well to remove any soldering fluid remaining, the spot is dried, and the sides of the first and last turns filed flat, so as to make a square shoulder. The laminations are then strung on the spindle, with the square gaps in perfect alignment with one another. To ensure this, a little piece of wood cut squarely to the size of the gaps (⅜ in. by ½ in.) should be inserted in the channel. The laminations should now be placed between the jaws of a vice with the spindle lying across them, and the vice tightened so as to squeeze the laminations as closely together as they can be made to go. While things are in this position, the shoulder end of the spindle being pushed tightly against the laminations, another coil of four turns of No. 18 wire is wound round the free end of the spindle, close against the laminations, and these are also soldered, like the former, to the steel rod; and, as before, the superfluous ends are cut or filed off. The armature can now be removed from the vice, and any irregularity either in the circumference or in the channels filed up, the wooden block being removed and shifted from channel to channel until all three have been squared up. If the job has been carefully executed, we shall have about 1 in. of spindle projecting at one end, and 2 ins. at the other, the laminations being held firmly in place by the two coiled wire rings. We can now try whether the armature will rotate freely in the tunnel of the field magnets A, Fig. 2, with a clearance of $\frac{1}{32}$ in., or thereabouts, all round. If not, its diameter must be cautiously and equally reduced all round by filing until the desired clearance is obtained. The commutator next demands our attention. A piece of brass tube, about ¾ in. in diameter and ¾ in. long, is plugged with a piece of hard wood, cut cylindrically so as to fit tightly into the tube. The ends are cut off flush, and sand-papered up quite smooth. The tube should then be polished on the outside. By means of a pair of compasses, the exact centre of each end of the wood plugging is now found and marked; then with an ⅛-in. drill a hole is put through the centre of the wooden plug. (This should be a tight fit on the spindle of the armature.) As the brass tube has to be divided into three equal segments, in order to prevent these falling away from the wooden hub, we must fasten them to the wood before dividing in such a manner that each segment is insulated from its neighbour and from the spindle. To do this we turn the cylinder up on one end, and mark out with the compasses on the brass ring three equidistant points round the circumference. From these points we scratch, rather deeply, three lines on the face of the brass tube, reaching to the other end. Turning the cylinder again on end, we trace three lines across the wooden hub *just inside* the three points just marked off. (See Fig. 4, in which A is the central hole for the spindle B B B, the three equidistant points C C C being the lines marked across the wooden hub.) With a very fine metal saw, we cut down along these lines for the depth of about ⅛ of an inch through both wood and brass tube. We now invert the cylinder, and produce three precisely similar saw-cuts in the opposite end, taking great care that these cuts coincide *exactly* in position with those at the opposite end. Having selected a piece of thin sheet brass, or copper, of the same thickness as the kerf left by the saw, we cut from it six little strips ⅛ in. wide, and just long enough to reach from edge to edge of the ring when pushed in the saw-kerf. Placing the cylinder on one end, we insert these strips in the three cuts, and then neatly solder the ends of the strips to the brass tube. Again inverting the cylinder, we insert and solder the three remaining strips in the opposite end. We now carefully file off any superfluous solder. The ring or tube being now held firmly in position by the strips, we divide the brass into three equal segments along the lines previously scratched with a fine metal saw, going down sufficiently deep to sever the tube and just touch the wooden hub, but no farther. This completes the commutator, which can now be pushed on the spindle at the 2-in. extremity until it reaches to just ½ in. of the end of the armature. To ensure the commutator remaining rigidly attached to the spindle, it will be well, before pushing down the commutator, to rub a little glue (to which a drop or two of vinegar has been added) round the spindle at this point. The proper position for the commutator relatively to the armature is such that the *slits* along the commutator coincide with the *centres* of the arms of the armature.

§ 5. Before proceeding to wind the armature, it will be well to make and fit the bearings, mount the field magnets on a little base, and make the brushes. The base consists in a little block of mahogany, or oak, nicely planed up, 6½ ins. long, 4½ ins. wide, and ¾ in. thick. Two small blocks of wood, 1¼ ins. square, and of sufficient thickness when laid one at each end of the base to allow the field magnets to rest squarely on them with the outer curve of the tunnel just level with the base board, must be prepared, and then glued on the base board, one at each extremity across its length, at ¾ in. from the edges. Measuring across the width of the base, these blocks should stand at 1¼ ins. from one edge, and therefore 2 ins. from the other. These blocks having been firmly glued down, the field magnet is placed squarely across them, and fastened down to the base by two strips of tinned iron, 1¼ in. wide, bent thus: , passing tightly over the inside winding of each lower limb, and screwed down firmly to the base board. To make the bearings, two pieces of ⅛-in. brass, ¾ in. wide and 1¾ ins. in length, are bent into the shape of a letter L by the aid of a vice and a hammer. The lower bent piece should be nearly ¾ in. long, the upright piece being rather over an inch in length. These two portions in each bearing must be exactly at right angles with each other. In the shorter piece (the foot) of each bearing must now be drilled two ⅛-in. holes, to admit the screws which are destined to hold the bearings in place on the base board. In each of the upright portions, centrally and near the top end, we shall require to drill a ⅛-in. hole to admit the armature spindle. To find the exact position of this, we begin by wrapping smoothly and tightly round the whole length of the armature two or three turns of brown paper, until the armature fits quite tightly into the tunnel of the field magnets. We push the armature in the tunnel at right angles to the field magnets, and perfectly level with the base board; we ink the ends of the spindle and push the bearings against the ends of the spindle, so as to get a mark indicating where the holes are to be drilled. This being done, we can remove the paper from the armature; again insert it in the tunnel with the commutator end projecting over the 2-in. portion of the base board. We now put the corresponding bearing in its place, with the foot outwards, the upright portion within $\frac{1}{16}$ in. of the commutator. We also put the other bearing at the 1½-in. portion of the base board, bringing it up to about ⅜ in. from the back of the armature. We now try whether the armature can turn freely in its tunnel; if it do not, we adjust the position of the bearings until this is effected, when we mark with a sharp point pushed through the holes in the feet of the bearings the spots at which we shall have to drill holes in the base board to take the screws that serve to hold down the said bearings. The brushes are made out of very thin, springy sheet brass; about $\frac{1}{50}$ in. thick is quite sufficient. These should be about 1¾ ins. long and ⅜ in. wide, and bent exactly like the bearings—once at right angles—one ⅛-in. hole being put through the centre of the foot of each one.

§ 6. To wind the armature, we begin by "dressing" it wherever the wire has to lie, with brown paper, which should be glued carefully and smoothly in the three channels, and on the back and front of the armature. When this is dry, we take about 1½ ozs. of No. 20 d. c. c. copper wire (say 7 yards), and cut it into three equal lengths of 7 ft. each. Taking the armature in the left hand, with the commutator end facing us, we wind with one of the lengths of wire one of the projecting teeth, starting on the left-hand side of the tooth, and coming back on the right-hand side, laying the wire on tightly and evenly until we have wound on all the seven-feet length, with the exception of about 2 ins. at the beginning and at the end, which we twist together for future connection. We then turn the armature through one-third of a revolution, so as to bring another tooth uppermost; and this we wind in precisely similar manner, starting against the left-hand side of the cog and ending on the right-hand side, twisting up the two ends as before. Lastly, we wind the third cog as the previous one. We now give the wire coils a coat or two of shellac varnish, which will not only improve the insulation, but help to keep the wires in their places during subsequent treatment. When this is quite dry, we untwist one pair of wires, and with a penknife scrape off the cotton covering from the projecting portions, and clean the copper wire by scraping until the surface is quite bright. Proceeding to cog No. 2, we serve *its* wire in like manner; then we twist up tightly and neatly together the end of wire of cog No. 1 to the beginning of wire of cog No. 2. We now untwist and bare the wire ends of cog No. 3, after which we join (by twisting) the end wire of cog No. 2 to the beginning wire of cog No. 3, and the end wire of cog No. 3 to the beginning wire of cog No. 1. Fig. 5 will give the reader an idea of the mode of winding and finally joining the wires; for the sake of clearness, only one layer of wire is shown. The twisted ends of the wires are pulled straight, and cut off at such a point that they just reach the brass segments of the commutator. Each twisted end is then soldered neatly to the edge of that commutator segment which lies immediately below it. Our task is now nearly complete. Placing the armature in the tunnel, we put a little washer of cardboard over the end of the spindle to prevent the commutator coming into actual contact with the bearing. We then screw the front bearing down in its place, as previously marked. Going to the other end of the spindle, we fit another similar cardboard washer (3/8 in. diameter is ample for both of them) on the spindle, against the wire. We then slip on the other bearing, leaving a little end play, and screw it likewise down on the base. If all the fitting has been carefully done, the armature can now be spun freely round on its bearings, without either touching the tunnel or getting "set" in its bearings. We now screw the "brushes" in place—one each side of the commutator, with the longer portions resting *lightly* against the brass segments. Before driving the screws quite home, we bare the ends of the No. 18 wire projecting at *e* and *e′* of the electro magnets, and coil a turn of this wire under the heads of the screws holding down the brushes. After having cut off the superfluity with a pair of pliers, we screw up tightly. This completes the connection to brushes. We now insert a couple of binding screws in the base board at about 1 in. from the edge of each corner on the commutator side; and, bringing down and baring the ends of the wire left at *c* and *b*, we fasten these respectively under the shoulders of the above-mentioned binding screws. A small grooved wooden pulley may now be keyed to the spindle at the other end, where the commutator is not. This little motor will work well with a single bichromate battery, or with two dry cells in series; but it may be worked with perfect safety, and with greatly increased power, by any number of bichromate cells *in series* up to six, or of dry cells not exceeding nine.

TWO USEFUL BATTERIES.

§ 7. Notwithstanding the fact that the dynamo has to a great extent taken the place of the battery as the source of electricity for nearly all industrial purposes, there still remains a very large field in which the employment of the battery is more convenient. This is especially true in the case of amateur work, in which it is rare that a heavy current is required for any length of time together. In making up a battery, due regard must be had to the particular purpose for which it is intended to serve. An ideal battery or cell would be one which would give out all the energy contained in the zinc in the shape of electricity, with the minimum loss from internal resistance, the longest possible duration, conjoined to a perfectly steady output, or "constancy," and the maximum of electromotive force. In practice, these conditions are never attained all together. We shall therefore describe two useful forms, one of which is capable of supplying steadily a fairly large current at a rather low voltage for a very long time, and which has the great merit of not consuming any of the materials used in it, except when the circuit is closed; so that it may stand idle for a year or more without deterioration, and is always ready for instant work. The other form is one which is capable of giving for short periods

FIG. 6

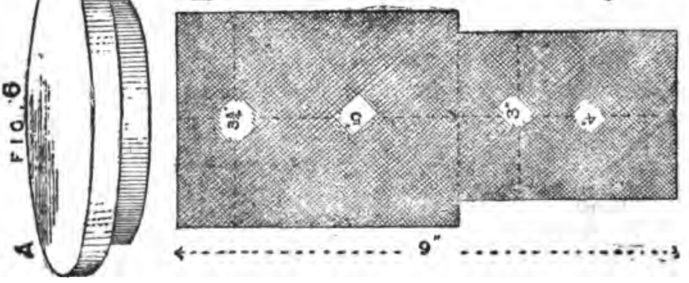


FIG. 8.

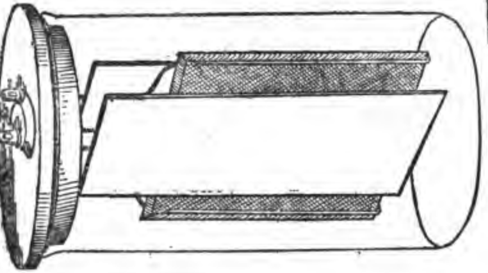


FIG. 9

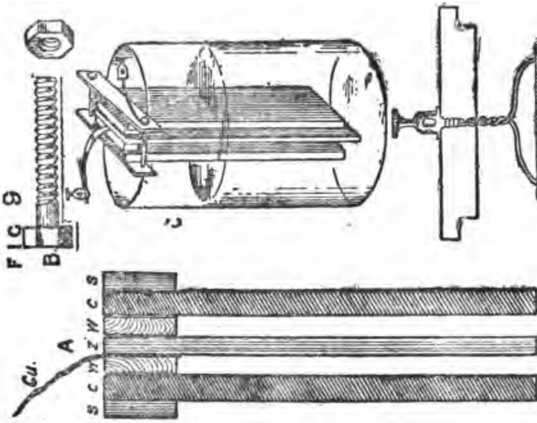
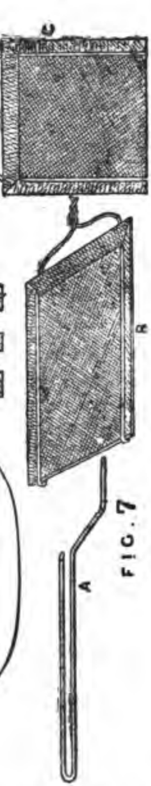


FIG. 7



(of about an hour or so) a very large current at a much higher voltage; but which will not admit of the elements being left in the fluid when the cell is not doing useful work, as the fluid attacks the zinc even when the circuit is not closed.

§ 8. The first cell we recommend the student to make is a modification of the *Lalande-Chaperon.* For this purpose he will procure one or more glass jars (according to the number of cells he desires to construct) 6¾ ins. in height and 3½ ins. in diameter. These jars can be obtained from almost any grocer's, as they are similar to the ones in which the 2 lbs of French plums are sent out. These jars must be now fitted with wooden covers, which can be cut out with a saw, from pieces of deal board 1 in. thick. They should be cut a little larger in diameter than the top of the jars, say 3¾ ins., and made into as true a circle as possible without a lathe by filing round the edges with a rasp. This being done, the operator will make a mark all round the edge of cover with a pencil at half an inch from the top; then, with a flat rasp or file, he will produce a shoulder in the cover by rasping away the wood on one side of this line for a depth of about ⅜ in., so that the cover can enter loosely into the neck of the jar and rest on the shoulder. The illustration A, Fig. 6, will make this clear. A little paraffin wax should now be melted in a flat tin, using only a gentle heat, and the wooden cover or covers allowed to soak therein until thoroughly permeated, which is evidenced by the wood ceasing to give off bubbles, and then removing and allowing to drain. This is done to render the wood insulating and waterproof.

§ 9. The next step is to make the copper oxide plate. For this, a piece of copper gauze, having about thirty-two meshes to the inch, will be needed. Each cell will take one copper oxide plate, the size of the gauze for which will be 9 ins. long by 3¾ ins. wide. Taking a strip of this size, the operator will fold it across near the middle, leaving 4 ins. on one side of the fold and 5 ins. on the other. On the 4-in. side of the line he will cut off each edge (until he reaches the line of folding) a narrow strip ⅜ in. wide, detaching these strips by cutting *on* the 4-in. folding line. At the opposite end, viz., on the 5-in. side, he will cut off two similar strips, but only 1 in. deep. Fig. 6 B shows the gauze when these strips have been removed. A paste is now made by mixing together 4½ ozs. of black oxide of copper (ordinary commercial) with ½ oz. of plaster of Paris, with just sufficient water to make a stiff paste, which must be immediately spread over the wider portion of the gauze strip, on the 5-in. side, to the depth of about ⅛ of an inch, reaching nearly to the protruding edges on the sides, and to within 1 in. of the top edge. The narrower piece of gauze is now folded over the paste just spread on, flattened down so as to hold the paste in position, and then the side and top edges carefully turned in so as to entirely preclude any escape of the black oxide of copper paste. The envelope or bag of copper oxide thus produced should be placed between two flat boards, on which is placed a heavy weight, and left in this condition until set quite hard. In order to be able to fasten this plate to the cover or lid, and to make a good connection to the outer terminal, it will be necessary to grip the plate between two copper wires, which are twisted together at the top of the plate, and thence passing through the centre of the cover, making contact with the shank of the terminal. Fig. 7 A shows one of these wires bent so as to grip the plate; Fig. 7 B shows the plate with the two wires in position; and Fig. 7 C illustrates the plate attached to the cover, with the terminal in contact with the wires. The size of the copper wire is that known as No. 16.

§ 10. Two zinc plates, 2½ ins. wide, 5 ins. long, and anything between $\frac{1}{32}$ and $\frac{3}{32}$ thick, are now procured, and in the centre of the narrower edge of each is soldered a straight piece of No. 14 copper or brass wire, about 2 ins. long. Before soldering this wire in place, it should be run through a screw-plate, so as to put a thread on it, and a couple of square or hexagon brass nuts made to fit it. A semi-circular piece of thin sheet brass, the shape of a letter C, and about 2 ins. in diameter, is now cut out, and a hole put through each corner, of sufficient size to allow the wires coming from the zinc plates to slip through easily when the nuts are removed. Placing this strip (without the zinc plates) on the cover, with the terminal centrally between the horns of the C, two marks are made in the wood at the spot where the holes are; then, removing the semi-circle, two holes are drilled through the cover at these points of sufficient diameter to allow the wires proceeding from the zincs to pass freely through. The two zinc plates are now placed one on one side, and the other on the opposite side, of the central copper oxide plate, the wires going through the cover, and through the C-shaped piece of copper. The nuts are then run down the screwed wires until the zinc plates are held firmly in place. The arrangement will now present the appearance of a sandwich, of which the copper oxide forms the middle, and the two zincs the outer portions. It must be borne in mind that these plates must not touch one another. In the centre of the C piece a hole is now drilled through to the wood, of such a size as to admit the shank of a second terminal being screwed in. The cell is now complete. Fig. 8 gives an idea of its general appearance.

§ 11. To charge this cell, dissolve 7½ ozs. of caustic soda (not washing soda) in 3 pts. of water, and add, when dissolved, 1 drachm of hyposulphite of soda. Pour in sufficent of this solution to just cover the copper oxide plate; then, lifting the cover slightly, add carefully enough vaseline oil to form a layer about ½ in. thick on the top of the soda solution. This latter prevents evaporation, and also protects the caustic soda from the action of the carbonic acid of the atmosphere. If by any chance the operator cannot readily procure caustic soda, he can easily prepare the solution from common washing soda in the following manner: 1 lb. of washing soda is dissolved in 1 gall. of water; ½ lb. of good fresh quicklime is slaked with cold water, until it falls into a fine white powder. This is added, with constant stirring, to the soda solution, and the mixture put in a clean, cast-iron saucepan, to which a lid can be fitted. This is now placed on a good fire, and made to boil for five minutes; the cover is then put on and the saucepan removed from the fire. It should now be allowed to stand for twenty-four hours, after which the *clear* portion should be carefully poured off the sediment, and stored for use in well-stoppered bottles. The addition of about 1 per cent. of hyposulphite of soda to this solution is advisable, though not obligatory. Each cell of a battery thus made has an electro-motive force of 0.7 volt, with an internal resistance of about 0.06 ohm only; so that on the short circuit it can give as much as 11 ampères. But its best discharge-rate lies between 1 and 2 ampères; and under these conditions it has a capacity of about 50 ampère hours. In other words, it can supply current at the rate of 1 ampère for 50 hours. The cell can be set aside for months after setting up without deterioration or any dissolution of the zinc, provided the surface of the liquid be well covered with vaseline oil. Three such cells *in series* give an E.M.F. of 2.1 volts, or a trifle more than a single bichromate cell; while in point of constancy, and there being practically no consumption of zinc when the battery is not coupled up, they are far and away superior to the bichromate cell.

§ 12. There are, however, many cases in which a cell capable of giving a very heavy current at a high voltage, if even for a, comparatively speaking, short time, is to be preferred to the one just described. Our second cell is therefore one of this type, and is known as the *chromic acid cell.* To make this, we use, as before, a 2-lb. French-plum jar as the outer containing vessel. Two carbon plates 6 ins. long, 2½ ins. wide, by about ⅜ in., and one zinc plate of the same size, but only ⅛ in. or $\frac{3}{16}$ in. thick, will be needed. The zinc plate must be well amalgamated by rubbing over both surfaces with a pledget of tow moistened with dilute sulphuric acid (1 part acid to 20 water), a globule of mercury being put on the surface of the zinc plate while the rubbing is going on; and the rubbing continued until the entire surfaces of the zinc are as brilliant as a mirror. The plate should then be rinsed and allowed to dry. Two strips of thin wood (a piece of cigar-box will do very well) about 3 ins. long and 1 in. wide should now be prepared, and soaked in melted paraffin wax (see § 8). Besides these, we shall require two pieces of ⅛-in. hoop iron, 1 in. wide and 5 ins. long; two ¼-in. bolts, 1½ ins. long, with their nuts; and a strip of thin sheet copper (about No. 25 gauge) 1 in. wide and 4 ins. long. Placing the two 5-in. pieces of hoop iron one over the other, we drill at half an inch from both extremities a full ¼-in. hole to admit the passage of the bolts. If we have not a drill sufficiently powerful for this work, any shoeing-smith can do it for us. We then place one of these strips on the table, with a bolt through the hole at each end, the head of the bolt lying on the table. On this strip we place one of the carbon plates, with its top edge level with the top edge of the iron hooping. Over this, and also flush with the top edge of the carbon plate, we lay a strip of the paraffined wood. In the centre of this wood strip we place our piece of thin copper at right angles to the wood, making a ⊥ with it, leaving about three inches projecting. Over this we place the zinc plate, then the other wooden strip, followed by the other carbon plate. Lastly, we put on the other 5 in. × 1 in. iron strip, causing the bolts to pass through *its* holes. We then put the nuts on the projecting screws of the bolts, and screw these nuts down tightly—so tightly that the carbons and the zinc are held rigidly in position, *not touching* one another. To the copper strip the shank of one terminal may be soldered; and if a second nut be placed over one of those holding down the hoop-iron strip, a loop of No. 16 copper wire may be clenched between the two nuts, and to this wire a second terminal may be soldered. To charge this cell the following solution, which gives excellent results, may be used:

Chromic acid	6 oz.
Water	1 qt.
Chlorate of potash	½ oz.
Oil of vitriol	6 oz.

Dissolve the chromic acid in the water; then add the chlorate of potash, and stir with a tobacco-pipe stem, or glass rod, until dissolved; then add the oil of vitriol in a fine stream, with constant stirring. The solution becomes hot; allow it to get quite cold before use. Each cell of such a battery has an E.M.F. of two volts, with an internal resistance of not more than 0·05 ohm when fresh, so that on the short circuit it is capable of giving as many as 40 ampères. This is a most powerful cell; and for short experiments requiring a large current, it is the best of its class. At the conclusion of each experiment the elements should be lifted bodily out of the acid, and the plates plunged into boiling water as far as the acid has reached, and allowed to stand therein for five minutes to remove any adherent acid, and then stood up to drain and dry. By doing this the plates may be kept in good working order for a very long time. Care must be taken ***never to leave the plates in the acid*** when the battery is not actually being used. Our Fig. 9 illustrates at A the arrangement of the carbon and zinc plates, with the intervening wood strips; and at B we have the kind of bolts and nuts to be used to clamp the whole together; while C represents the completed cell ready for action. Caution:—The young electrician cannot be too careful in using oil of vitriol (sulphuric acid). It should be poured out slowly, avoiding any splashing, for a slight spill of this powerful acid on the hands or clothes would result in serious injury.

A 1-INCH SPARK COIL.

§ 13. A good spark coil is an extremely useful and instructive piece of apparatus. By its aid, many beautiful and interesting experiments can be performed, such as the production of X rays, or of Hertz' wave effects, the perforation of glass, the preparation of ozone, the bringing about the combination of oxygen and hydrogen, the decomposition of water, the lighting up of vacuum tubes, working a wireless telegraph, &c. As it is our intention shortly to give instructions for making this latter, we trust that the following constructional details for building a good "Ruhmkorff" or induction coil, may prove acceptable.

§ 14. We shall need to provide ourselves, for this purpose, with the following articles: (*a*) a bundle of soft iron (technically known as "iron tails"), No. 22 gauge, 8 ins. long, 1 in. diameter, perfectly straight, and all cut to exactly the same length; (*b*) ½ lb. of No. 18 double cotton-covered copper wire; (*c*) 1 lb. No. 38 silk-covered copper wire; (*d*) 1 lb. paraffin wax; (*e*) two squares of well-seasoned mahogany, 3½ ins. × 3½ ins. × ⅜ in.; (*f*) a mahogany board, 10 ins. × 6 ins. × ¼ in., and two strips about 17 ins. long, ¼ in. thick, 1⅛ in. wide; (*g*) four "telephone" terminals, two of which should be ¾ in. long from the shank upwards, and two rather longer, say, 1 in. long; (*h*) a ¼ lb. of tinfoil; (*i*) one dozen sheets of demy paper, about 22 ins. × 18 ins.; (*j*) one sheet of stout brown paper; (*k*) half an inch of No. 18 gauge platinum wire; (*l*) six inches of round brass rod, ⅜ in. diameter, and three inches of similar rod, ⅛ in. diameter, also a small piece of brass sheet, $\frac{3}{32}$ in. thick, about the size of a penny; and finally (*m*) a short piece of thin clock spring (steel) $\frac{1}{32}$ in. thick and ¼ in. wide.

§ 15. Having provided these necessary articles, we begin by making *the base*, from the mahogany, in the form of a shallow box or tray, 10 ins. long, 6 ins. wide, with a clear space inside, 9½ ins. × 5½ ins. × 1⅛ ins. deep. This we make by cutting the 17-in. strips into two 10-in. lengths and two 5-in. lengths, mitreing the corners, and then glueing them so as to make a truly rectangular frame, which in its turn is glued on the 10-in. × 6-in. piece. When quite set and dry, the latter portion is then yet further strengthened in its attachment to the frame, by the insertion of eight small mahogany dowels (two in each side) reaching through the plank into the frame itself. These dowels should be neatly cut off flush with the plank, with a sharp penknife. In the four inner corners of the box thus produced must be glued four triangular pieces of wood, ¾ in. high and about 1 in. on the widest face.

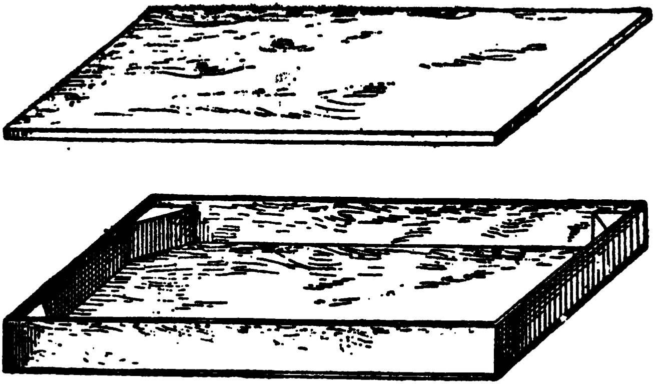


Fig. 10.

These serve to strengthen the corner joints, and also to support a false bottom, which is to be made out of a piece of thin deal, 9½ ins. long by 5½ ins. wide (this false bottom is to be left loose, and not fastened in until the coil is finished). This box, which constitutes the base, may now be polished, or simply varnished, at the option of the operator. In use, it will stand with the mahogany side uppermost, and the movable bottom downwards. The finished base is shown upside down, with the bottom over it, at Fig. 10.

§ 16. We can now proceed to make *the condenser.* For this, we begin by folding five sheets of the demy paper three times the long way, and twice the narrow way. Then, with the aid of a sharp penknife and a metal rule, we cut out sixty squares of paper 6 ins. × 5 ins. We put about ¼ lb. of paraffin wax in a flat square baking tin, of sufficient size to contain a sheet of paper lying flat, and applying heat below gradually, until the wax is all melted—we immerse and withdraw, one by one, the sheets of paper, allowing the superfluous wax to drain off from one corner of each before final removal from the tray. Each sheet should be suspended by one corner with a pin, on a line, to cool and set. Fifty squares, 6 ins. × 4 ins., are now to be cut, with penknife and rule, from the quarter lb. of tinfoil, a sufficient number of sheets of which have been previously folded into the nearest size to admit of this. (It is better to fold both the paper and the tinfoil into the nearest sizes, and cut each material at one operation with one stroke of the knife, than to cut each sheet separately, as the sheets come out much more uniform in size.) Having prepared these sheets, we procure a square of rather stiff cardboard, 6 ins. × 5 ins., and, laying this on a flat table, we put on it two or three sheets of paraffined paper, truly and squarely with the edges of the cardboard. We then take one of the sheets of tinfoil, and lay it on the paper in such a way as to leave a margin of paper ½ in. wide all round, except on the extreme RIGHT-hand edge, where the tinfoil will extend beyond the paper for ½ in. all along. We now take another sheet of paraffined paper, and place it squarely over the first sheet, pressing it down flat. A second sheet of tinfoil is now laid on the centre of this last paper, precisely as was the first; with this difference, namely, that the piece which overlaps the paper must be on the LEFT-hand side. Over this we place a third sheet of paraffined paper, followed by a third sheet of tinfoil with its edge extending over to the *right*, then a fourth sheet of paper and a fourth sheet of tinfoil over-lapping to the *left*; and so on with alternate sheets of paper and tinfoil until fifty sheets of tinfoil have been laid on, care being taken that all the odd numbers project on the *right*-hand side, and all the even on the *left*. We now place two or three sheets of paraffined paper over the last sheet of tinfoil, putting over all another square of cardboard, 6 ins. × 5 ins.; bind the whole tightly round by lapping over the narrower width with tape, which can be stitched down on arriving at the opposite extremity, leaving the over-lapping tinfoils projecting at the longer ends. This completes the condenser proper; but for facility of connection to

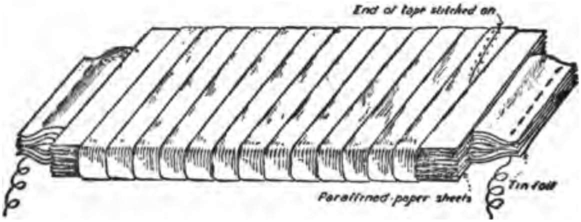


Fig. 11.

the other parts of the coil, it will be well to take a piece of No. 24 bare copper wire and stitch it in and out along the edge of the tinfoils projecting, say, on the right; and leaving a length of about 1 in. of wire free for future attachment. The sheets projecting on the left-hand side are now stitched in precisely the same manner. The completed condenser is shown at Fig. 11.

§ 17. The next thing that claims our attention is *the contact breaker.* A piece of ⅜-in. round brass rod is drilled and tapped longitudinally with a hole about ½ in. deep in the centre of its circumference, and of such a diameter as to take a ⅛-in. Whitworth. (This screw should be cheese-headed and about ¾ in. long.) A brass washer about ½ in. diameter, $\frac{1}{10}$ in. thick with a central hole of sufficient size to allow the aforementioned screw to pass freely in it, is now procured, placed over the hole in the rod, and the screw inserted. This washer serves to prevent the wood of the base from being cut when the contact pillar is screwed up tightly. At exactly 1¾ ins. from the bottom of this rod with the washer on, a transverse hole is to be drilled through the rod parallel to the washer. This hole will then be tapped with a ⅛-in. tap, and a screw made out of a bit of ⅛-in. brass rod, about ⅝ in., to fit nicely in this hole. From the $\frac{3}{32}$-in. brass sheet is cut a true circlet ⅝ in. in diameter, a hole put centrally through this, and one end of the aforementioned screwed rod inserted and sweated into the hole by means of a little good solder. A little fine milling should be put round the edge of this circlet with a "rose," if the operator possesses one; if not, by carefully filing indentations with a small triangular file. In order that this screw (which is called the "platinum screw") should not work loose, it will be well before inserting it into the hole in the contact pillar to slit the head of the pillar with a very fine hack-saw in a line with the hole. The slit should be carried about ¼ in. below the hole itself, and the tap run through the hole to remove any burr caused by the hack-saw. Then, if the sides of the pillar be slightly squeezed between the jaws of a pair of pincers, sufficient springiness will be given to the sides to enable them to grip the screw firmly without the aid of a back nut. With a very fine drill (about $\frac{1}{20}$ in. diameter) we now make a hole about $\frac{3}{32}$ in. deep in the centre of the tip of the contact screw, and into this hole we insert and afterwards burr in a short piece of No. 18 platinum wire, leaving ⅛ in. projecting beyond the tip of the screw. To make the vibrating portion we take a ⅛-in. Whitworth cheese-headed brass screw about ¾ in. long, with small hexagon nut to fit. In the slit of the head of this screw we fit and solder a piece of clock-spring 2 ins. long and ¼ in. wide. In this spring we drill two holes, one at 1¾ ins. from the bottom of the head of the screw, and another at ⅞ in. therefrom. Having chosen a piece of *very soft* round iron, ⅝ in. in diameter, we saw off a slice ½ in. long, and having filed up the two faces perfectly flat, we put a small hole, about ¼ in. deep, in the centre of one of the faces, which hole we tap to take a small metal screw. We then screw this iron "bob" to the top end of the spring. This spring should vibrate at such a rate (if sprung) as to give the note A, one octave below the middle A of the pianoforte. If it is sharper it is too stiff, and the entire spring must be cautiously filed; if it is much flatter the "bob" itself should be filed, or, better, a stiffer spring adapted. A very much thinner piece of steel spring is now filed up and cut to about $\frac{3}{16}$ in. wide by 1 in. long. Two holes are drilled into this, one at the top end just large enough to admit the No. 18 platinum, and one at the lower end of the same size as the central hole

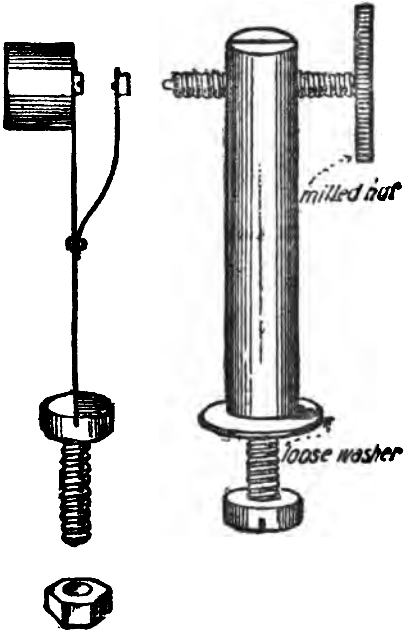


Fig. 12.

in the larger spring. In the former we insert and burr over on both sides by gently tapping with a flat peen-hammer about ⅛ in. of platinum wire; in the latter we insert a little rivet, which we pass also through the central hole in the larger spring, and keeping the platinum speck just inserted in a line with the centre of the iron bob, we rivet the whole together by a smart blow or two with a light hammer. Fig. 12 shows the two portions of the contact breaker.

§ 18. We can now proceed to make up and wind *the coil proper*, beginning with the primary. To this end we take our bundle of iron wire (which should have been previously rendered perfectly soft by heating to redness in a clear fire, and allowing to cool gradually by letting the fire go out), and make it into a neat cylinder by binding it tightly round spirally with rather wide tape, this binding being stitched down at the ends to prevent undoing. This cylindrical bundle of iron wire should be about 8 ins. long, 1 in. in diameter. The tape binding should then be heavily varnished with good shellac in methylated spirits. When this coating of varnish is quite dry, the No. 18 wire must be wound on in two layers, starting at ½ in. in at one extremity of the iron bundle, and ending the first layer at ½ in. from the other extremity; returning back over the first layer, and finishing at the starting end. About 6 ins. of wire should be left free, both at the start and the end, for future connection to terminals, etc. To prevent the wire from uncoiling while being wound on and when finished, both the starting and finishing ends must be tightly tied to the bundle by a piece of strong silk twist. Each turn of wire must be coiled as tightly, evenly, and as closely to its neighbour as possible; and the two layers must be in one continuous length, laid on in the same direction of coiling. When the iron wire has been wound with primary to satisfaction it should be plunged bodily in hot melted paraffin wax, allowed to remain there as long as bubbles are given off, then held up vertically and allowed to drain, and finally reared up on end to set. While this is cooling, we make up a little flour paste, and cut from our brown paper a strip 7 ins. wide and 28 ins. long. Taking the wound bundle, we straighten out the two 6-in. lengths of projecting copper wire, and we roll the brown paper *tightly* round the wound bundle, leaving the ½ in. of bare iron wire projecting at each extremity. While putting the brown paper on, we brush the inner surface over with paste, and by pressing with a rolling motion by means of a flat board, on a flat table, we produce a firm, hard cylindrical case over the iron bundle. This must be set aside to dry thoroughly, and while this is drying we can drill out a central hole in each of the 3½ in. by 3½ in. squares of mahogany which are to form the "heads" of the coil. These central holes should be nearly 1¼ ins. in diameter; they should be a very tight fit on the brown paper tube in which we have encased the iron core. When these holes have been put through the heads these latter should be heavily varnished with successive coats of good shellac varnish. When all is dry, the two heads are glued on the brown paper tube, one at each end, perfectly square the one with the other, and at right angles to the core, which should project about ¼ in. each end. When the glue is quite dry, the brown paper tube should itself be coated two or three times (allowing the varnish to dry thoroughly between each application) with shellac varnish. The two projecting ends of the primary, which we had previously straightened out,

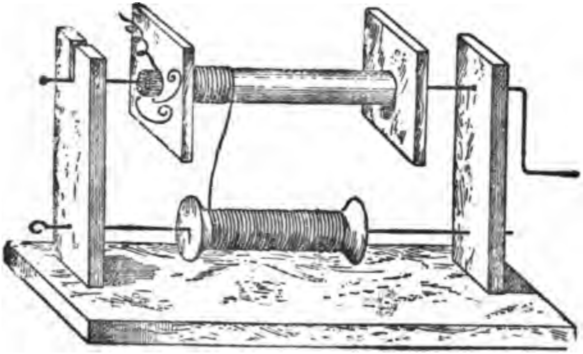


Fig. 13.

should now be carefully bent into a flat spiral, resting against the outside of the nearer coil-head, and then the whole mounted between two standards (see Fig. 13), merely for convenience of winding. Two ⅛-in. holes are made in the upper portion of these standards, exactly opposite each other. In one is inserted a 2-in. French nail, which passes into the centre of the iron bundle; and through the other is passed a piece of iron wire, about ⅛ in. diameter and 8 ins. long, which has been bent twice at right angles so as to form a handle. This is flattened at one end by filing lengthwise, and this end is pushed centrally into the opposite end of the iron bundle. By this means rotary motion can be imparted to the entire coil by turning this wire handle. Previous to mounting the coil between the standards, it will be necessary to drill a very fine hole (about $\frac{1}{32}$ in.) through one of the mahogany heads, to admit of the passage of one end of the secondary wire, which is the No. 38 previously mentioned. About 6 or 8 ins. of this wire are uncoiled from the reel on which it is sent out, and pushed through this hole from inside, outwardly, and the protruding portion coiled into a tight helix, so as to be out of the way. The reel is strung across the lower half of the standards by means of a metal rod. The operator now rotates the handle, and thus coils a layer of wire, closely, evenly, and smoothly, from one end to the other of the brown paper tube. The coiling should start at about ¼ in. from the inner face of the head, or flange, and terminate at about the same distance from the opposite head ; this is to prevent accidental sparking down to the iron core. When one layer of wire has been put on, without breaking or otherwise detaching the wire, a sheet of paraffined paper (prepared as described at § 16), of sufficient width to reach from head to head, and long enough to make *one full turn* round the core, is tightly rolled round the wire, and the winding continued, always turning in the same direction, but coming back again towards the starting point. Again we apply a sheet of paraffined paper, to be followed by a layer of wire, and so on, until the whole pound of wire has been coiled on. Each layer of wire should diminish in length by about $\frac{1}{16}$ in., and the greatest care should be taken in winding on, to avoid kinks, breaks, or unevenness of any kind. The wire should be tested for continuity by means of a battery and galvanometer. About twenty-five or thirty layers will be required to use up the pound of wire. When the wire has been laid on, the finishing extremity should be brought to the outside by putting a fine hole through the head of the coil which is opposite to the one at which we started, and passing the wire through this. These two holes should be in a line with one another, and in the opposite half of the square heads at which the primary wire ends project. The coil can now be removed from the winder. A couple of ⅛-in. holes about ½ in. deep are now drilled in the centre of the upper edge of each head (one in each), and into these holes are screwed the shanks of two ¾-in. telephone terminals. These should not be driven quite home until the projecting ends of the secondary wire have been bared of their silken covering, and coiled two or three times round the shank of the corresponding terminal, which, on being screwed down, will make good contact with the wire. The last layer of wire can now be covered with about half-a-dozen turns of paraffined paper, tightly and smoothly laid on. When the paper has been laid on, the lapping edge may be caused to adhere by passing over it a clean rod of heated iron. As a "finish" to this it will be well to bind this round with one turn of good silk velvet, either green or deep purple, stitching the join along the under part of the coil (where the terminals are not). The coil proper is now complete; so that we can proceed to mount it on its base, and connect it to the condenser and to the battery terminals.

§ 19. For this purpose we place the coil (terminals uppermost) on the base board, with *its* length parallel to the longest edge of the board, in the centre of the width, but with the primary wire head at 1½ ins. from one narrow edge; the other head being ½ in. from the other edge. With a sharp-pointed pencil we make a mark on the base board round the edge of each head; and also mark the two spots where the primary wire (still flatly coiled against one of the heads of the coil) can be brought down to pass through the top of the base board. Removing the coil, we mark two spots, one in the centre of each resting-place of coil heads. Having chosen two suitable wood screws about 1 in. long, we drill a hole

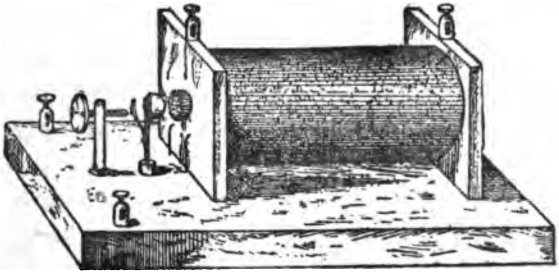


Fig. 14.

through the base board at each of these marked points of sufficient size to admit the screws chosen. These holes should be countersunk at the back (*i.e.*, inside the bottom) to allow the heads of the screws to be flush when screwed up. In like manner (only without any countersinking) the two holes through which the primary wires will have to be passed are put through the base board. The primary wires are now straightened out and made to point downwards, divested of their cotton covering, cleaned, and pushed through these holes. The coil and base are now inverted, care being taken to retain the coil in the exact spot previously marked on the board, the two screws inserted in their holes, and screwed tightly into the lower edges of the coil heads. We now put the two larger terminals in place on the base board—one at each corner of the narrow edge nearer the primary wire ends, at about 1 in. in from the edges, so as to clear the little blocks we have inserted below. (If these screws are fitted with nuts it will be very convenient, as this will avoid the necessity of soldering any connections.) We then bend one of the primary wires quite flat against the inside of the box, and take it to the nearest terminal, making the wire loop round it, and soldering thereto, or fastening it with a nut. We now place the vibrating hammer of the contact breaker on the base board in such a position that the iron "bob" faces the centre of the iron core, leaving a space of about $\frac{3}{16}$ of an inch between the face of the hammer-head or "bob," and the bundle of iron wire. We mark on the base board the exact spot this occupies, and having drilled a hole through the base we insert the screw from below. Under the head of this screw, before tightening up, we pass one turn of the other primary wire, leaving a length free for future connection to condenser. Taking the platinum screw pillar, we place it just behind the vibrating hammer spring, so that the platinum tip of the screw just touches the platinum boss on the spring when the screw is half-way through the pillar; and, having marked the exact spot on the base, we put a hole and screw through, just as in the case of the vibrating hammer. Under this screw-head we also put a turn of bare No. 18 copper wire, and connect this to the free terminal in the corner, leaving a length of this wire protruding, also for connection to condenser. The connections below are, therefore: from one terminal to contact pillar, through vibrating spring to one end of primary of coil; then back from the other end of primary to the other terminal. Care must be taken that none of the wires cross or come into contact with one another. This is particularly to be observed in the case of the two projecting wires which we have left for connection to condenser. Turning these two latter upwards (when the coil is upside down), we cover over the connections we have just made (to the exclusion of these two condenser wires) with two or three layers of paraffined paper. On these we lay the condenser—as near the end that is farther from the contact breaker as is possible. We then bring one of the projecting No. 18 wires flat along the side of the base, and solder it to one of the No. 24 wire extensions left on the condenser for this purpose (see § 16; latter portion). In like manner, the other free end of No. 18 wire is brought over and bent down so as to reach the other No. 24 extension on the condenser, to which it is soldered. The whole having been pressed down flat, sheets of paper, preferably paraffined, are put in the bottom of base until it is filled in to the level of the false bottom; so that when this is inserted the condenser is held firmly in place. The false bottom is then fastened to the base by a screw in each corner, reaching through to the four corner blocks. The coil, which is represented at Fig. 14, is now complete, and if care has been taken to follow the instructions as above, will be found to give a one-inch spark, if furnished with current from two or three of the chromic acid cells described in our last article.

A WIRELESS TELEGRAPH.

§ 20. The principles on which wireless telegraphy depend are very similar to those involved in the transmission of sound and of light. A wave motion set up at a given spot is propagated through the surrounding medium, and on striking certain bodies in its course sets up motion and a change of condition in them. We cannot appreciate the wave motion of light, but we become cognisant of its effects by the change it sets up in the retina of the eye, or on a photographic plate, etc. In like manner, the wave motion of sound is not perceptible to the eye, but is made evident to the ear when the wave impinges upon the tympanum and causes it to vibrate. In these two cases we have—firstly, a source of wave motion; secondly, a medium transmitting the wave motion; and thirdly, a receiver capable of taking up and utilising, or otherwise rendering evident, the wave motion.

§ 21. In the wireless telegraph we have to set up electric waves, and this can be done by the aid either of an induction coil (described in our last article), or by means of any static electric machine, such as the Wimshurst, used in conjunction with a sparking device called the "oscillator." The medium for transmission through which we have to work is the surrounding atmosphere, and to a certain extent the earth itself. The receiver consists essentially of a container, in which are placed particles of substances whose condition is altered by the impact of the electric wave, and of any contrivance whereby this change can be made evident either to the eye or to the ear.

§ 22. The transmitting arrangement. For our purpose, as the means of producing the electric waves, we may employ a coil made as described in § 13 *et seq.*, capable of giving at least an ½-in. clean fat spark. The battery suitable for use with this will consist of three cells of the chromic acid type described in the sections on batteries. Besides these we shall require a tapping-key, to make and break contact between battery and coil at will; also an oscillator, consisting of three insulated brass balls mounted on a stand and furnished with terminals for connection to the coil.

To make the tapping-key, we procure a piece of any hard wood, nicely planed up and squared, about 5 ins. long, 2½ ins. wide, by ½ in. thick. A piece of thin spring steel (side steels used in corsets will do), 4 ins. long, ¼ in. or ⅜ in. wide, two telephone terminals, one drawing pin, one ¾-in. wood screw, a strip of thin sheet brass ½ in. wide and 1 in. in length, a brass button, and a bit of round brass rod, ¾ in. long, $\frac{3}{16}$ in. in diameter. We begin by drilling a hole through the brass strip centrally, at ½ in. from one extremity, of such a size as to admit the passage of the shank of one of the terminals. At ½ in. from the opposite extremity, also along the central line, we make another hole just sufficient to let the point of the drawing pin pass through. Placing this brass strip on the base board, with its length parallel to the longest sides of the board and equidistant from them, the narrow edge lying flush with the narrow edge of the board, the smaller hole pointing inwardly, the operator will drive the drawing pin through

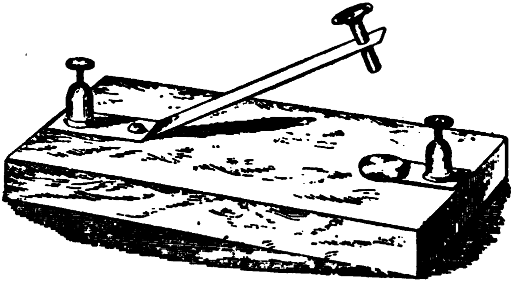


Fig. 15.

this hole, into the wood below, giving one or two taps with a hammer, to ensure the head of the drawing pin making good electrical contact with the brass strip. He will then drill a small hole in the wood just below the larger hole in the brass strip, into which he will insert one of the terminals, and screw it up until it bites the brass strip firmly. Having cleaned the brass button with a bit of emery paper, he will lay it face downwards (convexity uppermost) on any convenient place, and holding the ¾-in. piece of round brass rod perpendicularly on its centre by means of a pair of pincers, he will solder the rod to the button. Now taking the piece of steel spring with the pincers, he will soften 1 in. at one extremity and ½ in. at the other, by holding it over the flame of a spirit lamp until it has become dull red-hot at these points. Allowing the steel to cool *gradually*, the operator will bend the spring at an angle of 45°, beginning at 1 in. from the longest softened end. When bent, he will put two ⅛-in. holes in this 1-in. portion, namely, one at ½ in., and another at 1 in., from the extremity. The first must be large enough to allow the shank of the second terminal to enter freely; the second must permit the passage of the wood screw. Proceeding to the other extremity, he will drill, at about ¼ in. from the end, a hole to admit the $\frac{3}{16}$-in. rod (to which he had previously soldered the button). Cleaning up the spring with emery paper, especially where he held it over the spirit flame, completes this portion. He will then place the buttoned rod half-way through the hole last made, and solder the rod at right angles to the spring. Placing the 1-in. end of the spring on the base board, at the extremity opposite the drawing pin, he will adjust it at such a distance from the edge, that on pressing down the button, the projecting end of the $\frac{3}{16}$-in. rod shall strike the centre of the head of the drawing pin. Having found this position, he will fasten the spring down to the base by means of the wood screw in the interior hole, and finally put the shank of the terminal through the hole nearer the edge. The tapping-key is now finished—and it is evident that if it be placed in series with a battery, no current will pass, so long as the button is not depressed, but that the circuit will be completed every time that the spring is pressed down, so as to bring the end of the $\frac{3}{16}$-in. rod into contact with the head of the pin. Fig. 15 shows the completed tapping-key.

§ 23. The oscillators, or transmitter balls, can easily be made from three round brass bedstead balls, two 1 in. in diameter, one 1½ ins., a 6-in. length of ⅜ in. round ebonite rod (or, failing this, a 6-in. length of any ⅜-in. round hard wood rod, previously boiled in melted paraffin wax), two 6-in. lengths of ⅛-in. round brass wire, a couple of telephone terminals, and a flat base board in any hard wood, 9 ins. long, 3 ins. wide, and about ½ in. thick. The larger brass ball is fastened to the centre of the base board by means of a short peg of paraffined wood screwed into the flange of the ball and inserted in a suitable hole in the centre of the base board. As these balls have female screws in their collars, these attachments are easily made. At about 4 ins. from the centre of the board, on either side of the central ball, a hole is drilled ⅜ in. bare in diameter, to admit the insertion of two pieces of the ⅜-in. ebonite or wood rods. Before permanently placing these in their respective holes, a transverse hole must be drilled in each, at about ¼ in. from the top, of sufficient size to admit the passage of the ⅛-in. brass rods in the centre of the top of each rod; and reaching as far as the transverse hole just made, another hole must be drilled into which the shank of the terminal can be screwed. The two smaller brass balls are then fitted with the 6-in. lengths of ⅛-in. brass rod which are passed through a little plug of wood that is then screwed into aperture in the ball, the brass end being pushed in until it makes actual contact with the inner surface of the ball. All lacquer must be removed from the balls by means of very fine emery paper, and the balls themselves must always be kept brilliantly polished by rubbing with a chamois and rouge. The wires carrying the two smaller balls are now in-

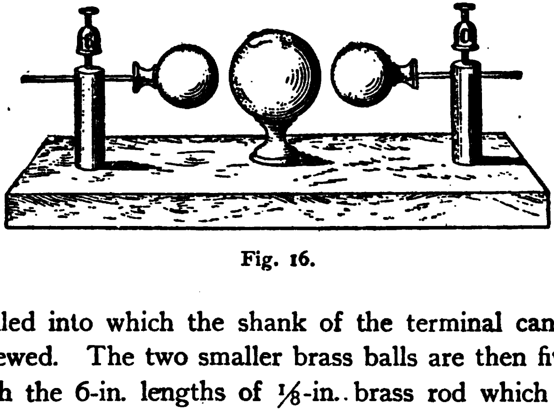


Fig. 16.

serted in the transverse holes at the top of the rods, and the rods themselves glued into their position in the holes of the base board, with the smaller balls in a line with and facing the centre of the large central ball. If the rods protrude below the under side of the base board in arriving at this position, they must be cut off flush with it. The two terminals are now put in their respective holes in the top of the uprights. They serve at one and the same time to make connection between the coil and the transmitter balls, and to enable the operator to set the smaller balls at any desired distance from the central one, and to clench the wires, so as to retain them in that position. Fig. 16 shows the completed arrangement.

§ 24. To make the receiver, we must provide ourselves with an ordinary 2½-in. electric bell, two flat pieces of board (12 ins. × 6 ins. × ½ in. thick), an empty brass cartridge case, about $\frac{3}{16}$ in. diameter, ¾ in. long (a No. 1 saloon gun cartridge will answer our purpose), a couple of yards of soft annealed iron wire (No. 22 gauge), 1 oz. No. 36 silk-covered copper wire, seven telephone terminals, two dry cells of any good make (size about 2 ins. diameter, 6 ins. in height), a quarter of an ounce of nickel or iron filings, a piece of very soft iron ($\frac{1}{16}$ in. thick, 1¼ ins. long, and ⅜ in. wide), and a piece of platinum wire (No. 30 gauge). The receiver consists of five essential portions—(*a*) the relay, (*b*) the coherer, (*c*) the decoherer, (*d*) the bell, or other appliance for rendering evident the signals, and (*e*) the batteries. We begin by putting together the base board on which these different appliances will stand; and to this end we make a chamfer $\frac{1}{16}$ in. deep and ½ in. wide centrally along the length of one of the 12-in. boards. Having run a little good thin glue in this chamfer, we place the other board with its 12-in. edge in the chamfer—so that it stands upright and perpendicular to the lower board. When the glue is quite dry, we further strengthen this by drilling two holes in the under surface of the lower board, one at each extremity, reaching into the upright board. We countersink these holes, and then insert a screw in each reaching well into the upright board, and screw up until the heads are flush with the under surface of the lower board. The base board should now present the appearance of ⊥ when viewed from its longer extremity. To make the relay we take a smooth pencil about ⅜ in. in diameter, and round this we roll seven turns of stout brown paper 2 ins. in length, fastening down each successive turn of paper after the first with a little paste or thin glue. When the tube has been thus formed it should be drawn off the pencil and allowed to dry. While it is drying the operator will make two discs out of cardboard; these should be 1 in. diameter, with a central hole to fit tightly on the outside of the tube just made. They should be about $\frac{1}{16}$ in. thick. These are to be glued on, one at each extremity of the tube, to form a bobbin 2 ins. long, with 1-in. heads. From the iron wire is now cut a sufficient number of straight pieces (2⅛ ins. exactly in length), to fill tightly the inside of the

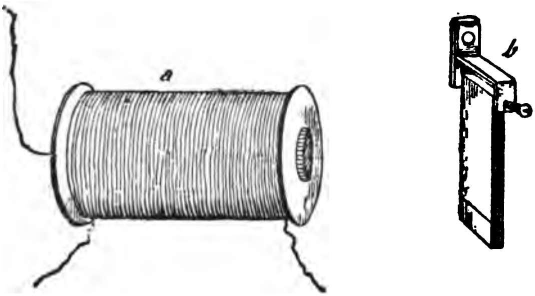


Fig. 17.

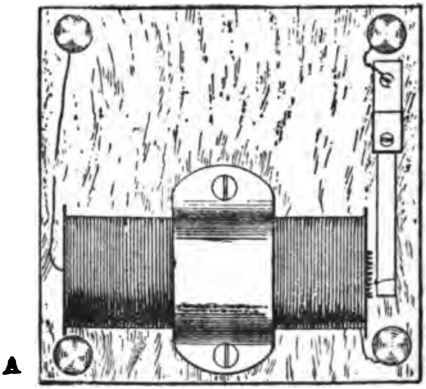


Fig. 18.

bobbin tube. These are pushed into the tube one after the other until it will hold no more. The ends of the wires must be flush with the tube at one extremity, and project about ⅛ in. at the other, where they must be filed perfectly flat. At this projecting end a small piece of platinum wire is pushed in centrally between the iron wires and the external portion coiled round upon itself, so as to form a little button about $\frac{1}{16}$ in. in diameter. A gentle tap with a flat-faced hammer will cause this coiled button to lie smooth and flat. The bobbin should now be wound with the 1 oz. of No. 36 silk-covered copper wire, leaving a length of about 3 ins. free at the starting end for future attachment to terminal, winding regularly and evenly from end to end, backwards and forwards, until all the wire is wound on in layers, except a length of about 3 ins., left for connecting up to the other terminal. In order that the finishing end should not fly back and uncoil, it must be tied down to the bobbin by means of a length of fine silk thread. This completes the electromagnet of the relay. To make its armature, we file up the small piece of soft iron till its dimensions are exactly 1¼ ins. long, $\frac{1}{16}$ in. thick, and ⅜ in. wide. At one extremity of this piece of iron we drill on the two edges, at $\frac{1}{16}$ in. from the top, two holes, one on each side, exactly *in a line with each other*, with a $\frac{1}{32}$-in. drill, to the depth of about $\frac{1}{16}$th of an inch. At the other extremity—across the wide face, and at about $\frac{3}{16}$ths of an inch from the bottom edge—we place a piece of platinum wire, and having bent the ends thereof round to the thin edges, we solder the platinum to the rim *at these edges only.* We now make a bracket in which to suspend this armature by taking a strip of brass, about 1/25 in. thick, 1/8 in. wide, and 2½ ins. long, and binding it four times upon itself so as to form something like an £, about 5/8 in. high. A pin-point 1/8 in. long is soldered to the centre of the lower right-hand projection. A hole is then drilled in the upper projection, exactly opposite the pin-point, and into this hole is fitted a 1/16-in. metal screw, the extremity of which must be tapered to a very fine point by filing. In the centre of the left-hand projection is also drilled a hole, to take a small wood screw. Standing this bracket in front of him, with the point and screw facing him, the operator puts the armature (with the platinum wire to the *left*) with the under hole on the pin point. He then screws down the upper screw until it enters into the upper hole—so that on lifting the bracket the armature can swing freely on the two points. Although it is possible to mount the relay on the base board direct, it is more convenient, for after regulation, to assemble the parts on a little separate base of its own; and for this purpose a little square piece of cigar-box wood, about 2½ ins. × 2½ ins., will be found most suitable. At each of the four corners is to be inserted a small telephone terminal, and under the right-hand terminal, previous to screwing down, is placed a short piece of No. 24 copper wire, which is passed round the head of the screw with which the bracket carrying the armature is to be fastened to the base—also to the right, and just below the terminal. The electro-magnet is now to be placed across the little base, with its platinum button facing the platinum wire crossing the face of the armature. A strap of leather or thin ebonite is now placed over the centre of the bobbin, when a screw put through each end of the strap will hold the bobbin firmly in its position on the base. A piece of No. 24 copper wire is now cleaned, and one end pushed in between the wires of the electro-magnet, at the flush end, whence it is brought up and passed under the flange of the top left-hand terminal, which is then screwed down upon it. One of the ends of the No. 36 wire wrapped round the bobbin is then brought under the left-hand lower terminal, the other end being in like manner connected to the right-hand lower terminal. It is needless to point out that, to ensure good electrical contact, these ends must be bared of their silken covering, and be well cleaned with emery paper, before being screwed up under the shanks of the terminals. Fig. 17 shows the relay; (*a*) is the electro-magnet, (*b*) the armature with its bracket, and Fig. 18 A the parts assembled on the base.

To make the coherer we take our empty little cartridge case and polish the inside perfectly bright by means of a small rounded stick and a little emery. To the centre of the closed end we solder a 4-inch length of No. 18 bare copper wire. To the open end we fit a little stopper cut out of any hard wood, which should enter into the case to a depth of $\frac{3}{16}$ in. only. Through the centre of this stopper we drill a small hole, to admit with tight fit of the insertion of one end of another 4-inch length of copper wire. This latter wire should be so far pushed in the stopper as to reach to within ⅛ in. of the bottom of the cartridge case. Having for security's sake given another final polish with the emery stick to the interior of the case, we pour in some fresh clean nickel filings (or failing nickel, iron filings) until the case is about half-full. The greatest care must be taken that the filings be free from rust or grease. The stopper is now inserted. This completes the coherer, which is shown in section at Fig. 18 B. We can now proceed to assemble the parts on the base board. Removing the hangers (if any) from the back of the bell, we place this horizontally on the top right-hand corner of the vertical board, with the little bob (which forms the hammer of the bell) downwards, and at 6 ins. from either end of the board. In this position it is fastened to the upright board by means of two 1-inch wood screws, inserted from the back. The relay is now fastened to the same upright by a screw put through from the front, near the centre of the top edge. It should be placed at the top left-hand corner. The screw should not be driven quite tightly home until the relay has been adjusted at its best position; that is, with the armature swinging just clear of the platinum-tipped pole of the electro-magnet. Two terminals are inserted in the base board, just below the level of the bell, at 3 ins. on each side of the bell hammer. The coherer wires are inserted in the holes in the terminals, and the wires adjusted so that the hammer of the bell only just clears the tube of the coherer; so that when the bell rings, the hammer, in falling back, taps lightly on the tube, and thus acts as a decoherer. A wire taken from the right-handed terminal of the relay bobbin is also inserted into the hole in the left-hand coherer terminal, which is then screwed up tight. A similar piece of wire is inserted in the right-hand coherer terminal, and brought to a terminal inserted near the bottom of the left-hand corner of the upright board. Two terminals are now inserted in the top edge of the upright—one to the left and the other to the right, at about 1 in. from each extremity. A wire is brought from the top right-hand terminal on the relay to the corresponding terminal on the edge of the upright board. A second wire is made to connect the top right-hand terminal of the relay to the top right-hand terminal of the bell; finally, a third wire is brought from the top right-hand terminal on the edge of upright to the lower terminal of bell. Fig. 19 shows the receiver mounted. To put it ready for action, one of the dry cells is connected up by wires to the relay terminals A and B; while the other cell

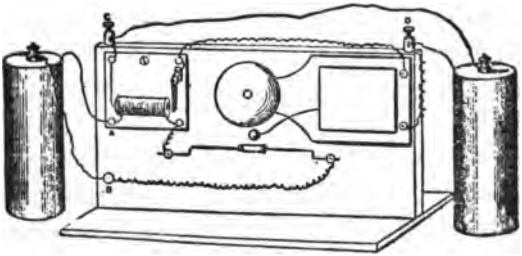


Fig. 19.

is connected to the bell terminals on the edge of the board, at C and D. As it is essential that no metal should be in front of the coherer, these two cells may be placed at the sides of the base board, or behind it.

§ 25. The enthusiastic amateur, having made the wireless set described in the previous sections, will find no difficulty in setting up the different portions of the apparatus, so as to cause it to work. However, for the benefit of those who have not had previous experience in this subject, and also to enable them to perform other experiments besides mere signalling, we propose here to give a very brief summary of the causes which produce the effects, and then to pass to the consideration of the applications to which these effects may be put.

§ 26. If by any means we give a charge of electricity to (or raise the potential of) an insulated body, we alter the electrical condition of *all* the surrounding bodies in a degree which bears a proportion to their vicinity. If the charge be given gradually, the effects are also gradual, and not easily recognisable; but if the charge be suddenly given, or as suddenly removed, the effects are more readily noticeable. As an example, suppose we gently depressed a board on the surface of a still pond, and as gently put pressure upon it, hardly any indications would show themselves (in the shape of ripples or waves) that any pressure had been placed on the water: whereas, if a small stone were suddenly thrown into the water, a series of waves, in the shape of rings, starting from the point of impact of the stone with the water, would give immediate evidence of the disturbance of the molecular condition of the water. It must be borne in mind that, in the case of *electric waves*, these are simply the effects of *stress* put upon the surrounding non-conducting medium, and are not electricity conducted *by* the medium. Just in the same way as waves in water can do work in striking against objects within their reach, so these electric waves can and do effect changes in the condition of surrounding bodies with which they may come in contact. One of the most striking of these effects is that of altering the electrical conductivity of bodies which are in loose mechanical contact. It is on this property that the power of signalling to a distance without wires is chiefly due. Let us fit a small glass tube, with a cork at each end, and push two pieces of clean copper wire through the corks until they nearly meet at the centre of the tube, leaving, say, about ⅛ in. gap between. If now we remove one of the corks, and having nearly filled the tube with medium-fine filings, either of brass, iron, nickel, etc., we re-insert the cork, we shall find, if we connect this tube (by its wires) in circuit with a Leclanché cell and a common galvanometer, that very little current will pass. If, now, while things are in this condition, a charged Leyden jar be *discharged* in the neighbourhood of this tube, even at the distance of several feet, a marked change will come over the conductivity of the filings in the tube; and the galvanometer will, by its greatly increased deflection, denote the passage of a much larger current of electricity. In fact, the electric wave, on striking the

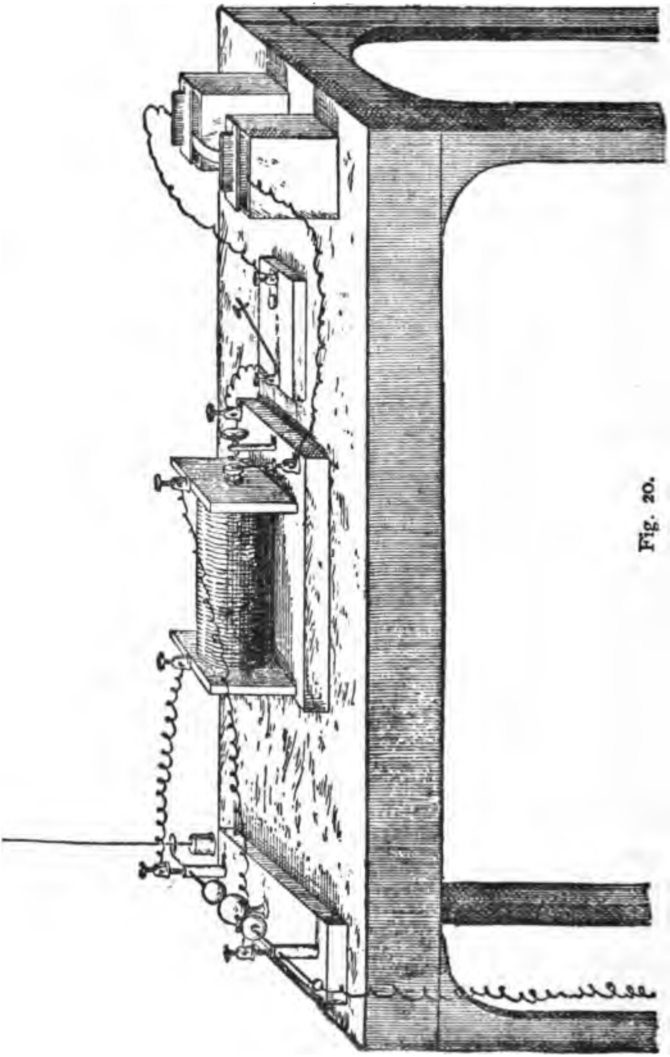


Fig. 20.

filings contained in the tube, arranges them in a set position, causes them to cohere slightly, and thus allows the current from the battery to pass to the galvanometer. But the slightest motion imparted to the filings, the merest tap or jolt, suffices to destroy this coherence, and lower the conductivity of the filings to its original point. On the application of these two simple facts the whole of the phenomena known as "wireless telegraphy" depends.

§ 27. In the preceding sections we gave directions for the construction of the *transmitting* apparatus. To use this properly, the operator will place his battery and coil on a convenient level table, and connect the battery, tapping-key, and primary terminals of coil, in series, with one another, as shown in Fig. 20 (to the right of the illustration). He will then connect, by two well-insulated wires, *not touching the table*, the secondary terminal of the coil to the terminals on the oscillator. If he is using a 1-in. spark coil, the two smaller side balls should be adjusted so that they stand at about 3/8 in. clear of the central ball on each side. On depressing the key, so as to make contact between battery and coil, the clapper of the coil should immediately start into action, and a virtually continuous stream of sparks should flow between the three balls of the oscillator. Should this not be the case, the distance between the balls and the adjustment of the contact-breaker of the coil should be altered until this result is unfailingly attained. The next step is to ascertain which side of the oscillator is connected to the terminal of highest potential of the coil. This will vary according to the relative connection of coil to battery, so that having once ascertained this point, it will be well to mark the battery and coil terminal, so as to be certain of always coupling-up in the same way. This can easily be ascertained as follows. Let an assistant depress the tapping-key, and while it is depressed, let the operator present his knuckle, first to the right-hand, and then to the left-hand wire projecting from the smaller balls on the oscillator. On one side he will obtain no spark; on the other he will perceive a thin, short spark, and feel a slight pricking sensation. This latter is of higher potential; and we will, for the future, call it the "positive" side. (The operator should not depress the key himself, nor yet come into contact with the assistant while *he* does so, otherwise he may receive a smart shock). Having ascertained which is the positive side of the oscillator, he will attach to it a metal rod (a common brass stair-rod will do nicely), by standing the rod upright against the wire projecting from the smaller ball on that side, and fastening it to the said wire, by two or three turns of any fine binding wire. The foot of this rod should be *insulated* by placing a little bit of sheet ebonite or glass between its extremity and the surface of the base board of the oscillator. Or, if the operator desires to be very elaborate, he may turn up a little circular stand in ebonite, like one-half of a cotton-reel, and having put a hole nearly through this at its centre, drive the end of the stair-rod into the hole. This rod is technically known as a "sky rod," and serves to present a larger radiant, etc., for the electric waves set up, than is afforded by the balls alone. In like manner, by means of a thin wire, a chain, etc., the opposite side of the oscillator is connected to earth. These connections are shown to the left hand of our Fig. 20.

§ 28. The transmitting portion being thus set up, we can turn our attention to adjusting the receiver. We will suppose that we make our first experiments in a room, although the apparatus described will work well through a distance of a mile or more if actuated by an inch spark-coil. We begin by placing the receiver at the farthest extremity of the room, opposite that at which we have set up the transmitter, with the coherer facing the transmitter balls. We then adjust the little square carrying the relay so that the armature *just clears* the pole of the electro-magnet. We then connect up the bell cell (the one to the right in Fig. 19, p. 53) to the two terminals on the top edge of the board. If the connections on the board have been properly made, it will be found that if we cause the armature to touch the pole of the electro-magnet the bell will immediately ring. This adjustment being satisfactorily made, we couple up the left-hand cell (see Fig. 19, p. 53) through the lower terminals on relay to the coherer, and back to cell. We now see that the little ball or hammer that strikes the bell gong just clears the coherer, and just touches it if the hammer-shank be sprung and allowed to fall back. This adjustment is essential, since, if the ball rests on the tube the ring will be thuddy and defective; if it clears the tube by too much the coherer will not decohere, and the bell will go on ringing, instead of giving a clean stroke or blow for each signal. The next step is to put the receiver "in tune" with the transmitter. Beginning at a distance of about 10 ft., produce a spark between the transmitter balls by a sharp tap on the tapping-key. (A spark of ⅛ in. should suffice at 10 ft. distance.) If the bell rings, well and good; if not, place a stair-rod (or similar piece of copper wire) resting against the left-hand terminal of coherer, and also on the table. Now try another spark. If it still does not ring, either lengthen the spark gap slightly, or tie (with fine wire) another "sky rod" to the central terminal of relay-coherer battery, letting the rod point upwards. The distance between the transmitter and receiver may be increased to almost any extent; but in proportion as the distance between the two increases, so must the lengths of the sky rods or "wings," affixed to the transmitter and receiver respectively, be increased. An increase in the spark gap between the transmitter balls also increases the penetrative power. It is hardly necessary to remark here that, in order to avoid accidentally running down the batteries or polarising the relay, it is advisable *never* to leave the batteries connected when not signalling. In signalling by bell, two modes may be adopted. First, by a pre-arranged code of rings, such as—

One stroke	I return.
Two strokes	Have a chop ready.
Three strokes	Detained on business.
Six strokes in three separate sets of two each	England expects every man to do his duty.

Etc., etc.

Or, secondly, by a succession of taps and trembles to take the place of the "dot and dash" symbols of the Morse alphabet. When the key of the transmitter is kept down, an almost continuous flow of sparks occurs at the transmitter balls, and this produces a continuous tremble of the bell in the receiver. This is equivalent to a dash "—" in the Morse system. If, on the contrary, the tapper be sharply tapped, and as sharply allowed to spring back, only one spark is produced between the balls, and the bell responds by one stroke only, which is equivalent to the dot (" . ") of the Morse system. For the benefit of those who prefer to signal alphabetically rather than by a code, we subjoin a table of the accepted Morse alphabet:—

A	. —	**N**	— .
B	— . . .	**O**	— — —
C	— . — .	**P**	. — — .
D	— . .	**Q**	— — . —
E	.	**R**	. — .
F	. . — .	**S**	. . .
G	— — .	**T**	—
H	. . . .	**U**	. . —
I	. .	**V**	. . . —
J	. — — —	**W**	. — —
K	— . —	**X**	— . . —
L	. — . .	**Y**	— . — —
M	— —	**Z**	— — . .

§ 29. It is possible with this same apparatus to light a lamp, or lamps, at a distance. To show this effect, the operator will disconnect the bell battery (the one to the right) from the terminals C and D. He will also disconnect the wire which starts from the upper right-hand terminal of relay from its attachment to the upper bell terminal. Having procured a suitable four-volt lamp, he will arrange this on any convenient stand or holder, and attach the wire just removed from the bell terminal to one loop of the lamp. Putting a four-volt accumulator in the place of the dry cell just disconnected, he will connect one pole of this by a wire to the terminal C of the receiver, the other pole being connected by a wire to the free loop of the lamp. Now, on causing a spark to pass at the transmitter, the coherer will act, and pull up the relay armature, which, making contact between the accumulator and lamp, will cause the latter to glow. The lamp can be put out at will by tapping the coherer with a light pencil, etc.

§ 30. In precisely similar manner, substituting a fuse for the lamp, a charge of powder may be exploded, a mine fired, or a ship blown up at any distance from the transmitter, provided the receiver is within the range of the electric waves set up. To make the fuse, take a piece of No. 20 d.c.c. copper wire, 12 ins. long. Bare its two extremities for a length of about ½ in. Double the wire in the centre, so that the bared ends lie level with each other. Get a piece of rattan cane, ¼ in. diameter, ½ in. long. Make two fine holes side by side up its centre, about ⅛ in. apart. Push the bared ends of the wire through, so that they project ¼ in. Twist up the longer ends into a tight twist, and sever and bare them at the junction, where they must be kept separate from each other. Now solder a tiny bit of No. 42 German silver wire (about $\frac{3}{16}$ in.) across the two short bared wires which project through the cane. Wrap one turn of stamp paper round the cane, so as to make a little cartridge about ½ in. long; stick the edge down. When dry, put a few grains of fine gunpowder in the cartridge—just enough to cover the cross wire, and fold in the paper so that the powder shall not fall out. If this fuse be put in the place of the lamp in the last experiment, attached to the accumulator and relay by the bared ends at the long twisted extremity, when the spark passes between the transmitter balls the fuse will be fired.

A COIL FOR IGNITION PURPOSES.

§ 31. Many of our readers are possessors of some form of automobile; and, doubtless, they have had trouble with the ignition arrangement. Since the disagreeable and untimely breakdowns which occur are very often dependent on the coil and its attachments, we give the following details for the construction of one of the best forms of sparking coil for ignition purposes, which, if carefully carried out, will enable the reader not only to make, if desired, but to repair any such coil if occasion demands.

At the end of the article we give the dimensions, gauges, and weights of wire required for constructing ignition coils of two sizes; one, capable of producing an inch spark in air, suitable for large motor-cars, and another, giving ⅜-in. to ½-in. sparks under like conditions and output, which is ample for small cars or for motor-bicycles.

§ 32. A few words as to the mode in which a coil acts will enable the amateur to proceed about his work in an intelligent manner. If two wires, P and S, are lying side by side, but not in electrical contact with one another, and a current of electricity be sent through P at the moment of *making* and of *breaking* contact with the source of current, "induced" currents are set up in S, one in the *contrary* direction to the exciting current at the instant of making contact, and another in the *same* direction as the original or "primary" current at the instant of breaking contact. If the two wires P and S be of exactly the same length and diameter, the primary and secondary or "induced" currents will have very nearly the same value in volts and ampères (pressure and quantity), except only the inevitable loss caused by distance, leakage, and resistance. But if we coil P into a spiral cylindrical form, and over it coil S in the shape of a very much finer and longer wire, we shall find that the E.M.F. or volts set up in S will increase in proportion as the number of convolutions of S exceed those of P; while, at the same time, the quantity of current, in ampères, will decrease in like ratio. Another peculiarity that we shall notice, when the wire is wound spirally, is that the coils of P react inductively *on themselves*, so that at the instant of breaking contact with the source of electricity, a momentary current is set up in P. It must be noted that all these effects are *transient*, and no results are to be observed, except only at the instants of making and breaking contact. The presence of a soft iron (wire) core, placed in the centre of the helix of wire P, greatly heightens all these effects simply by concentrating the magnetic field about the coils, instead of permitting it to stray. It must be borne in mind that the self-induced current set up in P at the moment of contact being broken, is in such a direction as to annul the effect produced on S, so that unless some means be employed to take up this "self-induction" current it will be found impossible to get long sparks from S. The device usually employed for this purpose is called a "*condenser*."

§ 33. To make, therefore, an efficient sparking coil the following parts are essential: (*a*) An iron core to concentrate the lines of force set up by the battery current; (*b*) a coil of comparatively coarse wire (called the "primary") wrapped round this core, through which momentary currents can be sent; (*c*) a coil of very fine wire (known as "the secondary") surrounding the primary; (*d*) a condenser for taking up the self-induction current of the primary; this consists of a number of sheets of tinfoil interleaved with paraffined paper or other insulating material; (*e*) an arrangement whereby contact can be rapidly made and broken between the source of electricity and the two ends of the primary wire.

§ 34. THE IRON CORE.—This should be made of the best annealed soft iron wire, No. 22 B.W.G., straightened out, and cut into exact lengths, as given at the end of this article, and sufficient in number to make up a solid cylinder of the diameter specified. In order to make a truly cylindrical core it will be well to procure two brass rings, the internal diameter of which is precisely that of the proposed core, to serve as gauges of the diameter; then nearly fill one ring with the straightened iron wires, place the other ring on the opposite extremity, and carefully fill up the space by pushing wires in from one end until the rings are a tight fit. As the wire, under this treatment, becomes slightly hardened, it is well to anneal it. For this purpose the cylinder, with its brass ring at each end, is wrapped tightly round with some fine "binding" wire in the space between the two rings. The core is then placed in a clear red fire, and allowed to remain there until the fire has gone out and got quite cold. The core is then carefully removed, any ashes blown away, one ring removed, and then bound tightly from one end to the other with spirally overlapping turns of strong white tape, about ¾ in. wide; the binding wire and the ring at the opposite end being removed as the winding on of the tape progresses. The tape must be pulled as tightly, and made to lap at the edges as evenly, as possible. On arriving at the end of the core, opposite to that at which the binding commenced, the tape must be neatly and strongly stitched down to its subjacent turn (of tape), and the superfluity cut off square with the end of the core. When, by these means, a perfectly straight, firm, and cylindrical rod has been produced, the entire core is plunged into a vessel containing melted paraffin wax, and after remaining therein until thoroughly permeated (which can be known by the cessation of air-bubbles) withdrawn, and allowed to drain while standing in a vertical position.

§ 35. WINDING THE PRIMARY forms the next operation. For this purpose the operator takes a hank of the wire of the gauge and weight hereafter mentioned, and laying one end of the wire at about ⅛ of an inch from the extremity of the core, ties it firmly to the core by means of a piece of strong silk twist. Three or four inches of wire should be allowed to project over the tie for future connection to terminals. Fig. 21 shows the core with the wire tied on ready for winding. Taking the core in his left hand, with the hank of wire to his right, the operator winds tightly, evenly, and closely, until he reaches to within ⅛ in. of the other end of the core. Here, without letting go the wire (which would uncoil), he ties it tightly, as before, to *this* extremity of the core. Continuing the winding, always in the same direction, he winds back over the

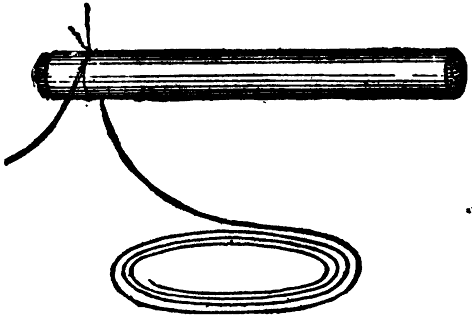


Fig. 21.

layer he has just laid on, with the greatest care to ensure tightness, evenness, and closeness. In fact, when the two layers have been wound on, they should lie as evenly as the turns of cotton on a reel. When the two layers have been satisfactorily wound on, the finishing end of the second layer should be very firmly tied down to the layer below by a turn or two of silk twist at the opposite diameter at which the starting wire stands. The tying the ends, the tight and even winding, are essential points to prevent the wire slipping during after-manipulations; so the core, when wound, should be perfectly hard, and the wire covering not grazed or bared at any place. The terminating wire should now be cut off, leaving, however, a length of about three or four inches free for after-attachment to terminal, etc. The primary being thus completed, it will be advisable to insulate once again; either by placing the entire wound core in melted paraffin wax as before, or by painting over the coils, especially at the extremities, with several coats of good shellac varnish, allowing each coat to dry thoroughly hard before applying the next. We can now proceed to—

§ 36. WINDING THE SECONDARY.—To effect this we cut a strip of stout brown paper of the same width as the wound core, and of sufficient length to make *seven* complete turns thereon if rolled tightly round. This strip of brown paper should be allowed to stand in melted paraffin wax until bubbles are no longer extricated. Taking it by one end, it is then to be rolled tightly and evenly round the wound core, so as to form thereon a solid, firm, and truly cylindrical tube, Should the operator find any difficulty in getting the paper to lie smoothly, or to adhere together at the termination, he will find his labour facilitated by holding a hot iron at a little distance from the paper, which, by melting the paraffin, will render the paper at once pliant and adhesive. If the extreme edges of the paper evince any tendency to detach from the layer below, or to curl back, the application of a little shellac varnish along the inner edge will cause it to adhere. While this is drying, the operator will prepare some paraffined paper, both for the insulation of the successive layers of secondary wire and for the construction of the condenser. He will choose any good, rather thin, white paper, perfectly free from holes or thin places. (That white wrapping paper known as "Demy," which is sold in sheets about 22 × 18 ins., will do nicely.) A perfectly clean flat tin dish is placed over any gentle heat, and in the dish is placed sufficient good clean paraffin wax to cover the dish to the depth of ½ in. when the wax is melted. The paper is then drawn, sheet by sheet, through this melted paraffin, held up by one edge to allow it to drain back into the dish, and, finally, hung up by one corner to set. By drawing the paper over the edge of the dish when removing from the paraffin, the excess of wax can generally be removed; should, however, the paper be unevenly coated at any place, it will be advisable to place the coated paper between two sheets of white blotting-paper and go over it with a moderately hot iron (not so hot as to scorch the blotting-paper), which will effectually remove any superfluity. When the paper has thus been prepared, it must be cut into long strips of the same width as the wound primary, but of increasing lengths to permit of each strip encircling the succeeding layers of secondary, the circumference of which perforce increases with the number of layers laid on. As it would be almost impossible to wind on the fine wire which constitutes the secondary by hand alone, it will be necessary to rig up a little winder, to enable the operator to do this smoothly and evenly. Two wooden uprights fastened to a base, with a rod passing through two opposite holes in the lower portion to support the bobbin on which the wire is wound off, and with two opposite slits to admit the passage of the support and crank for the core, will serve every purpose. To sling the core and primary, so as to enable it to be rotated between these standards, it will be necessary to drive a 2-in. French nail *centrally* to the depth of about an inch into the iron core at one end. At the other a piece of brass wire about ⅛ in. diameter and 8 ins. long, bent into the shape of a cranked handle, thinned and flattened by filing at one extremity, is driven in between the wires of the core as centrally as possible, also to the depth of about an inch. The entire core can now be slung between the slits in the uprights, and winding proceeded with by placing the bobbin of wire on the lower rod, as shown at A, Fig 22. As the secondary wire is very fine, and easily broken, it is advisable to start the winding of the secondary with two or three turns of a coarser wire, say, No. 28 silk-covered copper, leaving, as in starting the primary, two or three inches free for attachment to terminals, etc. The starting wire should be tied to the brown paper tube with silk twist to prevent slipping. When a turn or two of this coarser wire has been laid on, starting at about half-an-inch from the end of the tube, the end should be bared of covering, and soldered to the starting end of the fine wire on the reel below. The soldered joint should be carefully covered with a fold of paraffined paper, and then, by turning the handle, the fine wire carefully wound on to the brown paper tube as evenly and closely as possible, taking the greatest care to avoid kinks, loose places, or the wire overriding a previous turn. If a break should occur, the broken ends must be bared of covering and then

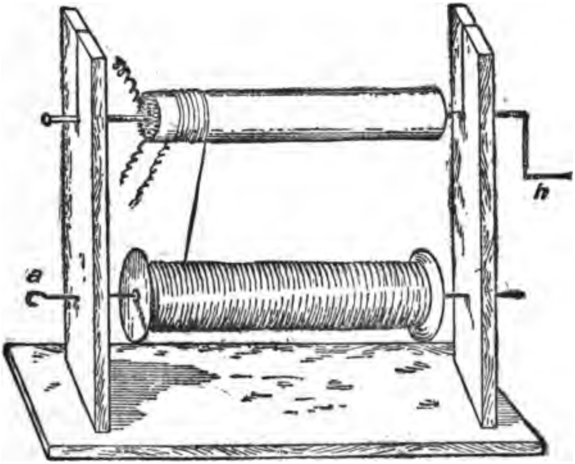


Fig. 22.

joined by soldering, rosin alone being used as flux, and the juncture neatly re-covered with fine silk. When the winding has reached to within ½ in. of the end of the core, the operator will take a strip of the paraffined paper sufficiently long to go once round the coil and lap a little over, and roll it carefully round the coiled wire, allowing the continuation of the wire to pass out between the edges of the sheet, where it laps over, in a line with the last coil below. This paper must be drawn tightly and smoothly over the coil of wire below, and fastened down by holding a warm iron against it, so as to melt the paraffin wax. Continuing to rotate the handle (always in the same direction), the operator will wind another layer on the paraffined paper towards the end from which he originally started, until he reaches to within nearly half-an-inch of the end. (N.B.—With each succeeding layer of wire laid on he will diminish the number of turns by two or three at each end, so as to avoid any tendency of sparking down towards the wire first laid on.) In precisely the same manner as above described, he will wrap this second layer round with paraffined paper and fasten down by warming as before, and so on, layer after layer, until the full amount of wire specified hereafter has been wound on. This, according to the operator's neatness in winding, will mean from 33 to 35 layers. As we require to bring the starting and terminating ends of the wire out at opposite extremities of the coil, we must manage the winding so as to get on an uneven number of layers. To prevent accidental breakage of the fine wire, we end off as we begun, by soldering a piece of coarser wire to the end of the fine wire, and finish off by two or three turns of the coarser wire, which we tie down as previously recommended. If these two coarse ends be coiled round a French nail (or any other convenient rod) into a little helix they are easily got at, and yet are out of the way. The wound secondary must now be carefully covered over with about a dozen turns of paraffined paper drawn round as tightly as possible, and bound round in several places with strong silk twist. The whole coil should now be removed from between the standards, the nail and the crank withdrawn, and be placed in a vessel containing clean melted paraffin wax until thoroughly permeated, then reared up on end to drain and cool. The paraffin used for these purposes should be of the best hard quality, and should have been previously melted once over dried powdered chalk (to remove acidity), and then decanted off from the chalk. Before proceeding to make the condenser it will be well to connect up the beginning of the primary wire

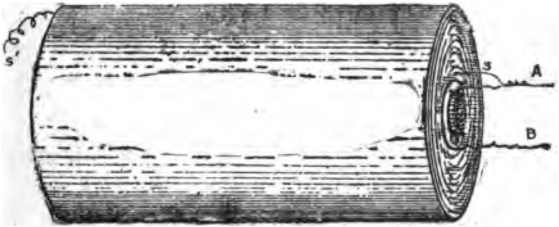


Fig. 23.

to the beginning of the secondary. For this purpose the ends of the wires are drawn out straight (see Fig. 23), and a portion of the primary wire A bared of its covering near the iron core. The end of the secondary at S is likewise bared, and wound round the bared part of the primary and neatly soldered together, using rosin as the flux. The joined portion should be neatly overwound with fine silk, and a coat of shellac varnish given to the covering. Finally, the termination of the secondary wire S′ having been also straightened out, sufficient melted paraffin wax is poured in and allowed to set, first at one end, and then at the other, of the wound coil, to fill up level and flush any interstices which may have been left by the draining away of the paraffin. We can now proceed with—

§ 37. MAKING THE CONDENSER.—For this purpose we cut 60 sheets of tinfoil, about 4 ins. × 3 ins. if for the smaller-sized coil, and about 5 ins. × 4 ins. if for the larger, all exactly the same size and truly rectangular, also about 66 sheets of paraffined paper, 1 in. larger each way—namely, 5 ins. × 4 ins. in the former, or 6 ins. × 5 ins. in the latter case. We divide the tinfoil into two sets of 30 sheets each, and having laid the sheets squarely and evenly on one another, we fold over one side, along the wider edge for a depth of about 3/8 of an inch, and with a smooth knife-blade press tightly down. With a fairly stout darning-needle, threaded with No. 30 bare copper wire, we stitch these leaves together, at about 3/16 in. from the edge, and having twisted the ends of the stitching-wire together, we cut it off, leaving about 3 ins. protruding, for after-connection to coil and terminal. By this means we shall have produced two booklets of tinfoil consisting of 30 sheets each. Three sheets of paraffined paper are then placed squarely over each other on a level table, with the narrow edge facing the operator, who then places one tinfoil book to his left, and the other to the right. Opening the left-hand book at the end sheet, he lays this tinfoil on the triple sheet of paper so as to leave an equal margin of paper all round, except along the edge, where the "back" of the tinfoil book is. Over this he places another sheet of paraffined paper, perfectly square with the one below. He now proceeds to the right-hand tinfoil book, and lays the first page of that over the second paraffined paper, leaving as before a clear margin of paper all round, except along the right-hand edge, which is alongside the "back" of the right-hand book. In this manner, placing alternately paraffined paper left-hand tinfoil, paraffined paper and right-hand tinfoil, he proceeds until the whole sixty sheets have been alternated with paraffined paper. Two or three sheets of paraffined paper are then placed squarely over the last tinfoil, then a square of white blotting-paper of the same size, and finally a fairly warm iron (hot enough to melt the paraffin wax, but not to scorch the upper paper) is placed on the blotting-paper and allowed to remain on till cold. This will squeeze out any superfluity of paraffin wax and make the whole into a solid block. Care must be taken to avoid, as far as possible, any superfluous paraffin getting on the two lateral extensions of tinfoil. By turning the "backs" a little upwards before placing the iron on, this can be prevented. If when cold the blotting-paper sticks to the iron, it can be detached either by gently warming the iron before a fire, or else by passing a flat knife-blade between the iron and the blotting-paper. The same applies to any adhesion to the table below. The finished condenser should now be cautiously and gently bent to the same curvature as the *outside* of the wound coil, the two tinfoil edges being parallel to the length of the coil. The best way to bend the condenser into this shape without cracking the tinfoil, is to get a cylindrical glass bottle of about the same size as the coil, warm it, and applying the condenser to its surface. gently coax it round the bottle, until it has acquired the desired curvature. Fig. 24 shows the completed condenser (with its projecting wires) bent into this form.

§ 38. CONNECTING COIL TO CONDENSER is the next task. As it is of the highest importance that the condenser be well insulated from the coil proper, it will be advisable to put a turn or two of thin $\frac{1}{64}$-in. sheet ebonite round the coil before fastening the condenser thereto. When this has been done the condenser is laid with its concavity against the convexity of the coil, at equal distance from each end and with its two wires protruding at the same end as the primary wires of the coil. When in this position it should be firmly lashed to the coil by binding round from end to end with rather wide silk ribbon, wound on spirally, neatly and tightly, and stitched down at the ends. The coil now shows five projecting wires, one at one end and four at the other. It will be remembered that at this latter end we had already joined the beginnings of the

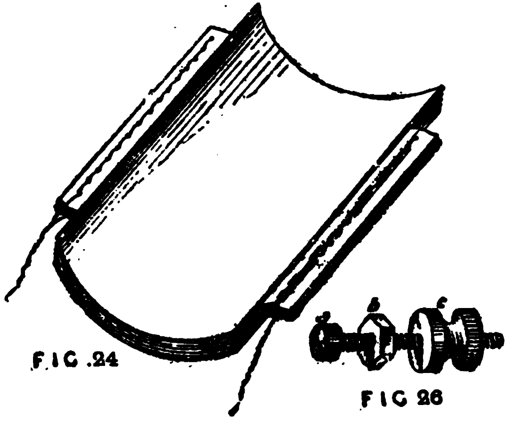


FIG. 24

FIG 26

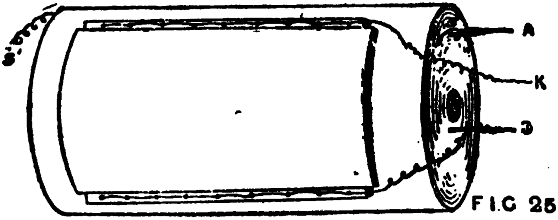


FIG 25

primary and secondary together (see Fig. 23, S and A). We now proceed to bare the primary wire B at about 1 in. from the coil, and having twisted one of the free condenser wires round it, we make a neat joint by soldering. All these soldered joints should be covered with fine india-rubber tubing, or, failing this, be wrapped round with a turn or two of thin india-rubber tape. The coil at this extremity has now three distinct wire ends (see Fig. 25). This completes the construction of the coil proper; all that now remains to be done is to fit into some kind of case.

§ 39. MOUNTING THE COIL AND FITTING THE TERMINALS.—It is really immaterial whether the coil be enclosed in a cylindrical case, as in the French type of coils, or whether in a square one, as in some of the English; what is essential is, that the coil itself should be thoroughly protected from damp or injury, and that the wires which come through to terminals should be thoroughly insulated from each other. For this latter reason the two extremities or "heads" of the coil-case should be of *ebonite;* and to hold the screws well these heads should be not less than ⅜ in. in thickness. We shall describe the mode of mounting in a cylindrical case, as being somewhat the neater. A piece of ebonite tube about 1 in. longer than the length of the completed coil and of sufficient inside diameter to admit the coil sliding easily into it is selected (this should be ⅛ in. thick). Two ebonite heads of ⅜ in. substance must now be turned up so as to fit closely into the two ends of this tube, a shoulder of about ⅛-in. depth being left, so as to prevent the heads dropping right into the tube. Four terminals, with central screws and double nuts, as shown at Fig. 26, are now procured. In the screw-heads of each of these a little pin is inserted at *a*, with a view to prevent the screw turning when the nut *b* is tightened. At three equidistant points around the circumference of the ebonite head which will fit over the three-wire extremity of the coil, and as near to the edge as the inner diameter of the tube will permit, holes must be drilled to admit the shanks of the screws, and these holes should themselves be countersunk, on the inner surfaces, to allow the heads of the screws *a* to lie flush. We now turn to the head which is to fit over that extremity at which the single secondary wire S′ (Fig. 23) projects. Here only one countersunk hole is required, and this must also be near the edge, the object being to keep this "live" end of the secondary from passing anywhere near the iron core, for fear it might spark down to it. For this same reason care must be taken in joining up the primary wire end to terminals, that the three wires neither cross nor even come near each other or the iron core. Close by the side of the countersunk holes through which the terminals pass, fine holes must be drilled clean through the ebonite heads, to allow the different wires to pass through, as all connections will be made on the *outside*. In order to fasten the heads on the tube, two or three small holes, to take small screws, must be drilled through the tube at each extremity, reaching into the edges of the heads where they enter the tube. All this preliminary fitting being done, the respective heads and the position of their screw-holes marked, the operator proceeds to put the whole together. Beginning at the single wire end (the secondary wire), he threads this wire through the fine hole, places the screw through the larger countersunk hole, and puts the coil in the tube and fits the head in position, taking care that the secondary wire comes straight up through the fine hole and distant from the core. By means of the little side screws he fastens the head on at this extremity. Baring the projecting wire at this end, he curls it once or twice round the bottom of the projecting screw. Over this he runs down the nut *b*, which he screws down tightly so as to clench the wire. Any superfluity of wire must now be cut off. Finally, the milled-head nut *c* is put in its place. He will now support the coil upright, in a vertical position, with the closed end downwards, and for future reference make some distinctive mark so as to know wires belong to condenser, to primary, etc. He will call A *secondary*, B primary and condenser. Having drawn these three wires straight up so as to be opposite their respective holes in the head, he will pour in sufficient melted paraffin wax (not too hot, so as not to injure

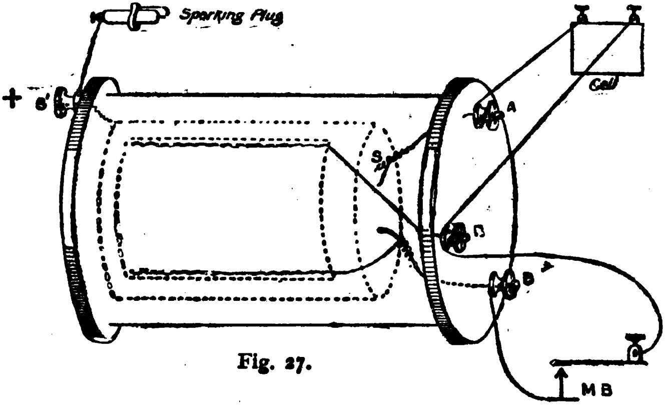


Fig. 27.

the ebonite tube) to fill in all interstices between coil and condenser, and reach near up to the level of the head when inserted. When this is cold and set, he threads the three wire ends through their respective holes, puts in the screws, puts the head in position, bares and cleans the three ends of wire, and grips them under the hexagon nuts *b* precisely as previously described. The milled-head nuts are now run on, the head fastened down by the side screws, and the letters A, K, and B marked by the side of their respective terminals. The coil is now complete and ready for work. When required for use, the terminals A and K are connected directly to battery or accumulator, taking care that the polarity of cell be such as to render the terminal S′ *positive* (see Fig. 27). When the correct polarity has been found it will be well to mark the terminal which should be connected with the positive wire of the battery with a +. If the cells or battery be properly connected to these terminals a spark can be drawn from the terminal S, by a knuckle presented to it every time contact is made and broken by a wire between K and B. By means of two separate wires the terminals K and B are connected up to the "mechanical break," as shown at M B. The terminal S′ is connected to the ignition plug. As the starting end of the secondary is connected to A, and thence through battery and primary to B, this latter being in its turn connected to frame of engine at the mechanical break M B, it is evident that when contact is made and broken at M B, the spark of the secondary can complete its circuit by leaping across the spark-gap in the plug to the metal of the cylinder, and thence home again through M B.

§ 40 Annexed is a table of the dimensions, gauge of wires, etc., required in the construction of these two coils:—

MATERIALS.	FOR COIL TO GIVE ½-IN. SPARK.	FOR COIL TO GIVE 1-IN. SPARK.
Iron wire core	4 in. long by ⅝ in. diameter...	6 in. long by 1 in. diameter.
Primary wire, d. c. c.	about ¼ lb. No. 20	about 6 oz. No. 20.
Paraffin wax	1 lb.	2 lb.
Secondary wire... ...	½ lb. No. 38 silk-covered ...	1 lb. No. 38 silk-covered.
Tinfoil	¼ lb.	½ lb.
Ebonite tube	5 in. long	7 in. long.

HOW TO MAKE A LINESMAN'S DETECTOR, WITH TWO COILS.

§ 41. A galvanometer, capable of indicating the presence of currents of considerable quantity (in ampères), or of fairly high pressure (in volts), is an invaluable instrument, not only to the electric bell fitter and telegraphist, but also to the practical electrician in general, as it enables him to ascertain the state of his battery and connections, as well as the presence or absence of leakage in the circuit.

The following directions will enable any worker, who is gifted with a little patience and neatness, to make up an instrument of this class, which, if purchased, would cost at least 30s., for about as many pence. The materials required are one or two empty cigar-boxes (cedar, if possible, as this takes a good polish), some thin sheet-brass (about 3 ins. by 6 ins.), not more than $\frac{1}{32}$ in. thick, a yard or two of No. 20 d.c.c. copper wire, one ounce of No. 36 silk-covered copper wire, three Post Office pattern terminals, a few No. 6 sewing needles, a strip of sheet brass about 3 ins. long, $\frac{1}{4}$ in. wide, $\frac{1}{16}$ in thick, a few small wood screws, one $\frac{1}{16}$-in. metal screw, a narrow strip of thin sheet-steel (out of a pair of stays will do nicely), about $\frac{1}{4}$ in. wide, $\frac{1}{8}$ in. thick, 3 ins. long; a sheet of clear glass, about 3 ins. by 4 ins., from which will be cut the glass front of the case; a piece of *white* cardboard for the dial, a little solder, and a strip of the thinnest possible sheet aluminium (for the pointer or index). Furnished with these, the operator will begin by making a case out of the cigar-box wood, which should be about $\frac{1}{8}$ in. thick, the outside dimensions of which should be $3\frac{1}{2}$ ins. in height, 3 ins. wide, by $1\frac{5}{8}$ ins. deep. These should be neatly glued together along the four edges with good hot glue, and clamped squarely together till quite dry, so as to ensure the parallelism of the sides and also of the top and bottom, as shown at Fig. 28. Four little strips of

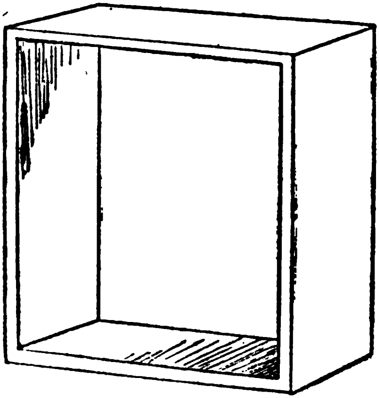


FIG. 28.

similar wood, ⅛ in. thick and ¼ in. wide, are now prepared of such lengths as to fit accurately in the inside edges of the case, just flush with its edges. These are glued in position, care being taken to "break joint" with the junctions of the case itself. A "back" of deal, or better, of American "whitewood," ¼ in. thick, 3¼ ins. long by 2¾ ins. wide, is now planed up to fit accurately into the opposite end of the box or case. This may be temporarily put in (but not fastened), and the box, after having been lightly sand-papered to remove any adhering superfluous glue, or other dirt, should be polished or varnished on the outside only. A piece of good, clear glass is now cut to fit easily into the case (the back being removed). This will form a front 3¼ ins. long by 2¾ ins. wide, and should not exceed 1/16 in. in thickness. Four more strips of cigar-box, ¼ in., ⅛ in. thick, should now be prepared, and varnished or polished, and then cut of such lengths as to fit accurately against the four sides of the box. These pieces are then brushed over with a little thin, hot glue, on the wider side, and fitted against the sides of the box, close to glass, so as to retain this latter firmly in place. (Care should be had in doing this not to soil the glass front with glue.)

The next step is to make the brass frame on which the two coils are to be wound. To this end, we take a strip of our thin brass sheet, and cut from it two pieces 2 ins. long, ¾ in. wide, and two other pieces 2 ins. long, ¾ ins. wide, at the upper and lower end, but extending on one side into half-moon-shaped lugs, about ¼ in. wide, as shown at Fig. 29, *a* and *b*. Each of these pieces is then slit down the middle to a depth of 1¾ ins., and a piece ¼ in. wide cut out of each, as shown in our Fig. The side lugs are then bent up at right angles, where indicated by the dotted lines. Three strips of thin sheet-brass are now cut, ¼ in. wide—two being ½ in. long, and one being 1⅜ ins. long. This latter is inserted into the slots cut in the pieces *a* and *b*, and soldered thereto, keeping the flanged pieces on the outside and the straight pieces in the inside, with a space of ¼ in. between the inner ones, and of ½ in. between the outer ones. In like manner, the remaining two ½-in. pieces are lowered into the slots (at the unsoldered ends) to a depth of a good ¼ in.

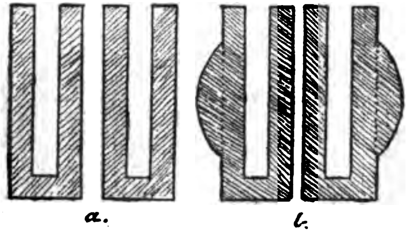


FIG. 29.

and soldered there—leaving the central portion *open* at this end, as shown in Fig. 30, A. We then take a piece of silk ribbon ½ in. wide, and wrap *one* turn tightly round the gaps between *b* and B, and also betwen *c* C *over* the strips just soldered in. This is done to prevent the edges of the strips from cutting into the insulation of the wires to be wound on the frame. For the same reason it is well to glue a ¼-in. strip of the same ribbon on the *inside* faces of the frame, care being taken not to encroach on the opening in the same, in which the magnetic needle will afterwards have to play.

This done, we wind the space, *b* B, with one layer (about eleven turns) of our No. 20 d.c.c. wire, beginning at the top left-hand corner of *b*, and ending against the flange at the right-hand corner. About 3 ins. of wire should be left free at these extremities for after-connection to terminals. To prevent uncoiling, both these extremities should be tied down firmly to the frame by means of a bit of silk twist. The side, *b* B, having been thus wound, the side, *c* C, is in like manner wound with the No. 36 silk-covered copper, in fifteen layers, each of thirty-one turns, as neatly and evenly as possible, starting against the left flange of *c*, and ending against the *right*-hand flange. As before, the extremities should project about 3 ins., and be fastened to the frame by tying with silk twist. The free extremities of these wires are now to be bared of their covering, by scraping with a penknife, to within ½ in. of the brass frame, and the two inner ones (viz., one No. 20 and one No. 36) twisted neatly together and lightly soldered; as shown at Fig. 31.

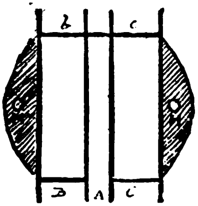


FIG. 30.

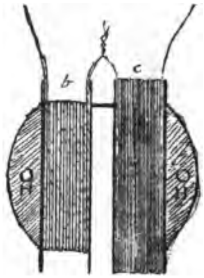


FIG. 31.

§ 42. We now proceed to make and mount a small magnetic needle from our piece of thin stay-steel. Taking hold of a piece of this by a pair of pincers, we heat it for a few seconds over the flame of a spirit lamp, so as to soften it. We allow it to cool gradually, and then file it up into the shape of a lozenge, 1¼ ins. long, $\frac{3}{16}$ in. wide at its centre. Exactly in the centre we drill or punch a minute hole, that will just allow one of our No. 6 needles to pass through it. We then heat our lozenge once again to a dull-red, and, while hot, drop it into cold water to harden it again. Having wiped and dried our lozenge, we sand-paper it all over, and magnetise it by stroking it from end to end (always beginning the strokes at the same end, and lifting off at the other) with the bare pole of a bar-magnet. We make, with a sharp, straight pin, a hole ⅜ in. deep in a piece of flat, soft wood; we then put a No. 6 needle through the central hole in our lozenge, and stand the whole upright on our piece of wood—the needle-point entering for exactly ⅜ in. in the pinhole just made. Taking care that this needle stands perfectly upright, we moisten the needle and the lozenge where they meet with a single drop of soldering fluid, and solder the needle to the lozenge with the smallest possible speck of solder. The needle (with its magnetised lozenge) should then be removed from the wooden block, rinsed, and dried, to prevent rusting. The mounted magnetised lozenge should present the appearance, and have the dimensions, shown at Fig. 32. To make the bracket which supports the needle and magnet that has to play between the two coils on the wound frame, we cut two strips of our $\frac{1}{16}$-in. brass—one 1½ ins. long, the other 2 ins. long. These must be filed up truly square at the edges, nearly ¼ in. wide, so as to enter freely in the gap between the two wound bobbins on the brass frame. The upper extremities of both pieces are then slightly rounded, and a $\frac{1}{32}$-in. hole put through the centre of the top of each (while they are held clamped together) at about $\frac{1}{16}$ in. from the edge. The longer strip is now bent twice at right angles, thus, __|‾‾‾, the first bend occurring at $\frac{9}{16}$ in. from the unpierced end, and the second at $\frac{7}{8}$ in. from the pierced end. These two pieces are then laid one on the other, with the pierced holes in perfect alignment one with another—the two limbs parallel, and two holes put through both in the shorter bend, of which one is to take a $\frac{1}{16}$-in. metal screw, and the other a small wood screw, as shown in section at Fig. 33, where the magnetised lozenge is shown in position, with its pivoting needle resting between the two holes, *a* and *b*. This latter hole is then somewhat enlarged, by riming out, to take a small glass pivot, made by drawing out a piece of $\frac{1}{8}$-in. glass tube into a cone, over the flame of a spirit lamp, and cutting off the pointed end with a small triangular file. This coned-glass pivot is inserted with its pointed end at *b*, and fastened into the hole with a trace of seccotine—care being taken not to allow any of this cement to enter into the pivot, as

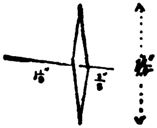


FIG. 32.

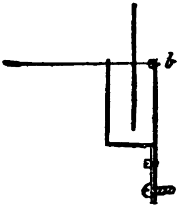


FIG. 33.

this would entirely destroy the freedom of the motion of the pivoting needle.

§ 43. We can now fit the parts together. We begin by screwing the wound frame, Fig. 31, to the whitewood back, with its slot central and parallel with the longer sides of the back, the top of the said frame (where the projecting wirings are) being ¼ in. from the top or narrower edge of the back. The screws that fasten the frame down should be round-headed brass ones and not exceed ¼ in. in the shanks. They are to be put through the holes marked H H in Figs. 30 and 31. We then make a little depression with a small bradawl, or a similar point, in the centre of the wood back, between the slot in the frame. This is to allow the pivot, *b*, Fig. 33, to rest in. We then let the bracket, Fig. 33, with its pivoted magnet, down between the slot in the brass frame, with the glass pivot resting in the depression just made, and screw it on the back by the wood screw—taking care that the pivoting needle is in the exact centre of the slot, and that the magnetised lozenge does not touch the brass frame at any part, but can revolve in the space between the coils with a clearance of ⅛ in. on either side.

Before going farther we must ascertain how much of the eye-end of the needle must be broken off, to allow the "back" to be inserted in the case without the needle actually touching the glass front. This will be as nearly as possible half an inch, but can be ascertained exactly by lowering the glazed case over the back and measuring the depth required. The needle must be broken off at its eye-end by holding between the jaws of a small pair of nippers, and giving the eye-end a sharp bend. The needle should then clear the glass by $\frac{1}{32}$ in., *not more*, otherwise it will work out of the pivot at the other end when the instrument stands vertically. The next operation consists in cutting out a square of white cardboard, to fit easily in the case, and to rest on the inner beading over the glass front. Having found where the pivoting needle touches this, we strike out from this point, as a centre, a circle $2\frac{1}{8}$ ins. in diameter, then an inner semicircle of only $1\frac{7}{8}$ ins. in diameter on the half. This we ink in, and divide into 90° on each side of a central line. We then punch out with a wad punch a $\frac{1}{4}$-in. hole at the centre of the circle, through which the broken end of the pivoting needle may pass and protrude. With a little good, hot glue we proceed to attach this graded card to the coiled bobbins of the brass frame, taking care that the card stands perfectly squarely and centrally, so that the case can be fitted over it with ease. The card should be slightly weighted on its upper surface to keep it *flat*, until the glue is quite dry.

A little index, or pointer, 2 ins. long, terminating in a point at one end, and widening to $\frac{1}{8}$ in. at the other or lower extremity, should now be cut out of thin sheet-aluminium, or, failing this, out of stiff, glazed black paper. A pin-prick is put through the centre of this to admit the broken end of the needle. By inserting temporarily a little piece of wood in the hollow space between the wound bobbins, the magnetised lozenge is held in a line with the slot, the pointer put on the end of the needle, wide end downward, and fastened in that position to the needle, at a distance of $\frac{1}{8}$ in. from the graded card, by means of a mere trace of warmed seccotine, which must be allowed to dry thoroughly before the little wood stay is removed.

If this has been nicely done, and the "back" be held vertically, the point of the index should stand at O° on the cardboard dial. All that now remains to be done is to insert the three terminals (and a ring if desired) in the top of the case, and to connect the former to the three wire ends coming from the wound bobbins. In order to do this in such a manner that the case can be opened for repairs, etc., without having to unsolder or cut any wires, the following will be found a good plan :—

Having put three equidistant holes in the top of the case, at ⅜ in. from the front, 1 in. apart, the operator will make three small nuts to go on the shanks of the terminals that will fit in these holes; he will also cut out six metal strips, ¼ in. wide and about 1½ ins. long, from the $\frac{1}{32}$-in. brass sheet, and put a small hole through the top of each. Having put the terminals in their respective holes, he causes their shanks to enter into the holes in their respective brass strips (which must point outwardly, towards the back of the case), run on the nuts, and

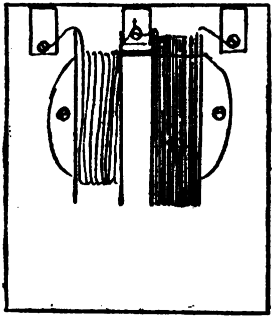


FIG. 34.

tighten up firmly. He then bends the strips downwards, at right angles, so that they press firmly against the back when this is inserted in place. He notes *where* these springy strips press on the back, and here he screws down the other three strips, gripping under the heads of the holding-down screws the three wires coming from the wound bobbins. To further ensure a good rubbing contact, the tongues of these last three strips may be bent slightly forwards, and any superfluity extending beyond the top edge of the back cut off flush (see Fig. 34). The back is then pushed in its place and fastened in by inserting a brass flat-headed screw in each side and at the bottom. A ring-screw may be inserted through the case into the back if desired. The left-hand and middle terminal will indicate *quantity*; the middle and right hand will show the tension or pressure of current.

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